SCHOOL OF
CIVIL ENGINEERING

INDIANA
DEPARTMENT OF TRANSPORTATION

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-94/1
Draft Final Report

ESTIMATING STATEWIDE VEHICLE-MILES TRAVELED IN INDIANA

Robert K. Kumapley
Jon D. Fricker

PURDUE UNIVERSITY

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-94/1
Draft Final Report

ESTIMATING STATEWIDE VEHICLE-MILES TRAVELED IN INDIANA

Robert K. Kumapley
Jon D. Fricker

Draft Final Report

ESTIMATING STATEWIDE VEHICLE-MILES TRAVELED IN INDIANA

Robert K. Kumapley
Jon D. Fricker, Ph.D.

Joint Highway Research Project

Project No: C-36-54VV
File No: 3-3-48

Conducted in cooperation with the

Indiana Department of Transportation

and

Federal Highway Administration

Purdue University
West Lafayette, IN 47907

January 20, 1994

TECHNICAL SUMMARY

Indiana Department of Transportation
Purdue University, School of Civil Engrg.
Joint Highway Research Project
West Lafayette, IN 47907
Phone: 317-494-2159

Estimated Statewide Vehicle-Miles Traveled in Indiana
Robert K. Kumapley, Jon D. Fricker
FHWA/IN/JHRP/94-1
Draft Final Report - January 20, 1994

Motivation

With strict environmental monitoring and more precise transportation planning now required under the 1990 Clean Air Act Amendments (CAAA) and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), the accuracy, stability, and growth rates of VMT forecasts is of primary concern. To achieve the desired accuracy in VMT estimation, the Federal Highway Administration has modified the Highway Performance Monitoring System (HPMS) to focus on VMT estimation. Presently the Indiana Department of Transportation (INDOT) estimates VMT by a method that follows closely the HPMS method taking advantage of the extensive amount of traffic records in the state road inventory. Because the state road inventory is focused on roads in the state highway system, INDOT is uncomfortable with the statewide VMT estimate. The statewide VMT estimate, which is expected to include all roads in the state network, is bound to be inaccurate.

Summary

Two cross classification models have been developed in this study for use in the estimation of statewide VMT in Indiana. This is to provide INDOT with an independent source of improved statewide VMT estimates based on driver behavior to supplement the estimates obtained from the traffic count based HPMS method. The models are calibrated to produce VMT estimates for all functional classes in the state network, including combined statewide VMT estimates for functional classes that are not part of the state highway system. The models are incorporated into a QUATTRO PRO spreadsheet program to allow INDOT simple and efficient execution of the models. The advantage of having the two models is to use the Short-term Model to forecast short term statewide VMT, and then use the VMT Tracking Model to track annually the VMT forecasts obtained from the Short-term Model.

Contact Persons: For more information, contact Professor Jon D. Fricker (317) 494-2205, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. JHRP-94/1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Estimating Statewide Vehicle-Miles Traveled in Indiana		5. Report Date January 20, 1994 6. Performing Organization Code
7. Author(s) Robert K. Kumapley Jon D. Fricker, Ph.D.		8. Performing Organization Report No.
9. Performing Organization Name and Address Joint Highway Research Project Civil Engineering Building Purdue University		10. Work Unit No. 11. Contract or Grant No. Indiana HPR-2068
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204		13. Type of Report and Period Covered Draft Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Two cross classification models have been developed in this study for use in the estimation of statewide VMT in Indiana. This is to provide INDOT with an independent source of improved statewide VMT estimates based on driver behavior to supplement the estimates obtained from the traffic count based HPMS method. The models are calibrated to produce VMT estimates for all functional classes in the state network, including combined statewide VMT estimates for functional classes that are not part of the state highway system. The results obtained in the model evaluation process indicate that the models are well calibrated. Model-generated VMT estimates are noted to be within 5 percent of Indiana VMT estimates published in Highway Statistics. The models were found to neither consistently overestimate nor underestimate the Highway Statistics VMT estimates.

The models are incorporated into a QUATTRO PRO spreadsheet program to allow INDOT simple and efficient execution of the models. The advantage of having the two models is to use the Short-term Model to forecast short term statewide VMT, and then use the VMT Tracking Model to track annually the VMT forecasts obtained from the Short-term Model.

17. Key Words		18. Distribution Statement No Restrictions. This document is available through the Nationtional Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 220	22. Price

Form DOT F 1700.7 (8-69)

Implementation Suggestions

The models developed in this study are based on data from NPTS and Highway Statistics that are specific to Indiana. Therefore, the models should only be used to forecast VMT on Indiana highways at the state level. However, procedures similar to those in this study may be adopted to develop similar models for other states or regions.

Because these are forecasting models, one must understand that model-generated forecasts are only as accurate as the input data and assumptions made about the future distribution of licensed drivers in the state of Indiana. Estimates of average annual miles driven with respect to sex and age category (see Tables A-3 and B-2) in the models are based on the 1990 NPTS. These estimates are assumed constant to 1996. The next NPTS is scheduled for 1995, and the survey data are expected to be available in 1996. The 1995 NPTS data may be used in updating the models. Also, information on the distribution of Indiana licensed drivers published each year in Highway Statistics may be compared with the distribution of licensed drivers generated by the short-term model. This is a simple and effective way of annually evaluating the forecasting capabilities of the short-term model.

It is important that the most current predictor variables be used in the models to guard against inaccurate forecasts.

Lastly, the results of these models must be approached as estimates, not actual values. Professional judgment must be applied to each forecast generated by the models. Each forecast should be carefully reviewed by the forecaster before any final recommendations and conclusions are made from model-generated statewide VMT forecasts.

Eventhough, it may not be possible to fully assess the monetary benefits associated with this study some benefits have been identified with the implementation of the results obtained in of this study.

Providing INDOT with a robust, simple and easy to use model will have several important uses, which include:

1. The models provide an independent source of statewide VMT estimates for comparison with the estimates obtained by the INDOT method.
2. The models provide INDOT with VMT estimates for functional classes such as minor collectors, urban collectors, and local roads which are neglected in the state road inventory.
3. The models enable INDOT to carry out sensitivity analyses leading to stable short-term VMT predictions and estimates of VMT growth rates that are obtained from VMT forecasts generated from the short-term model.
4. The VMT Tracking Model offers INDOT the opportunity to annually track their VMT forecasts obtained from the Short-term VMT Forecasting Model. The tracking of VMT forecasts is required in Section 187 of the 1990 CAAA.

Future research in developing VMT forecasting models is encouraged, because the models provide INDOT with an alternative source of VMT estimates to supplement INDOT's estimates. These models should be updated as future data become available. The models developed in this study should be continually monitored and updated when needed to ensure that the model-generated VMT estimates remain as accurate as possible. The QUATTRO PRO spreadsheet programs have been written to allow for easy updating of the models.

A long-term cross-classification VMT model originally planned for this study was not developed. This was due to unavailability of data specific to Indiana in NPTS surveys prior to 1990. Statistical tests were conducted in exploring the possibility of using national data in a long-term model for Indiana. The tests did not support the use of the national data in the long-term model for Indiana if accurate results were to be expected from the model. Future NPTS data are expected to contain specific data on Indiana that could be used in the development of a long-term VMT model. The short-term VMT model is designed to be used in conducting five-year forecasts. The long-term VMT model would be designed to predict VMT beyond 5 years.

TABLE OF CONTENTS

Page

Page

Page

Page

LIST OF TABLES

Table | Page

LIST OF FIGURES

ABSTRACT

Kumapley, Robert Kwasi. M.S.C.E., Purdue University, May 1994. Estimating Statewide Vehicle-Miles Traveled in Indiana. Major Professor: Dr. Jon Fricker.

The evaluation of Vehicle-Miles Traveled (VMT) estimation procedures to produce accurate and stable VMT estimates forecasts has attracted considerable attention over the past three years. With strict environmental monitoring and more precise transportation planning now required under the 1990 Clean Air Act Amendments (CAAA) and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), the accuracy, stability, and growth rates of VMT forecasts is of primary concern. To achieve the desired accuracy in VMT estimation, the Federal Highway Administration has modified the Highway Performance Monitoring System (HPMS) to focus on VMT estimation. Presently the Indiana Department of Transportation (INDOT) estimates VMT by a method that follows closely the HPMS method, but takes advantage of the 620,000 traffic records in the state road inventory, which is superior to the HPMS sample of approximately 4,000 records. Because the state road inventory data is focused on roads in the state highway system, INDOT is uncomfortable with VMT estimation for roads that are not part of the state highway system. The neglected roads consists mostly of minor collectors, urban

collectors, and local roads. The statewide VMT estimate, which is expected to include all roads in the state network, is bound to be inaccurate.

The objective of this study is to provide INDOT with an independent source of improved statewide VMT estimates based on driver behavior to supplement the estimates obtained from the traffic count based HPMS method. Two cross classification models have been developed -- a Short-term VMT Forecasting Model and a VMT Forecasts Tracking Model -- for use in the estimation of statewide VMT. The models are calibrated to produce VMT estimates for all functional classes in the state network, including combined statewide VMT estimates for functional classes that are not part of the state highway system. The models are incorporated into a QUATTRO PRO spreadsheet program to allow INDOT simple and efficient execution of the models. The advantage of having the two models is to use the Short-term Model to forecast short term statewide VMT, and then use the VMT Tracking Model to track annually the VMT forecasts obtained from the Short-term Model.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This research was conducted for the Indiana Department of Transportation (INDOT) to provide the Programming and Development Division with new methods and models toward improved statewide vehicle miles traveled (VMT) estimates in Indiana.

VMT estimates and forecasts are used extensively in the field of transportation planning with such applications as the allocation of resources, estimation of vehicle emissions, energy consumption computations, and traffic impact assessments. With strict environmental monitoring and good transportation planning practices now required under the 1990 Clean Air Act Amendments (CAAA) and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), the accuracy, stability, and growth rates of VMT forecasts are of utmost concern. Being one of the critical inputs (along with vehicle speeds and hours of travel) to vehicle emission estimation models, VMT forecasts must be as reliable as possible.

1.2 The Role of VMT Under the Clean Air Act Amendments (CAAA) 1990

The 1990 CAAA were signed by the President of United States on November 15, 1990. Under this Act, states that have areas designated as non-attainment areas are required to submit procedures in the revisions to their State Implementation Plans (SIPs) that they will follow to reach attainment by a specified date. These procedures are aimed at reducing forecasted travel and hence emissions, focussing on Transportation Control Measures (TCM) and other actions that may encourage alternatives to single occupant vehicles (SOV). The Environmental Protection Agency (EPA) and the United States Department of Transportation (USDOT) are required to submit an evaluation report to Congress every three years, beginning 1993, on the efficiency of federal, state, and local air quality related transportation programs required by the 1990 CAAA.

The EPA views growth in VMT as an indicator of growth in emissions and is very concerned about inaccurate VMT projections, because these may lead to inaccurate emission forecasts. VMT estimation, forecasting and tracking will therefore play a key role here in efforts to meet the EPA requirements. Forecasts of VMT and "actual VMT" are required for non-attainment areas each year up to attainment, beginning in 1993, with 1990 VMT estimates as base year estimates to be used in the forecasting process. These figures will be used to evaluate and monitor the performance of the SIP revisions.

For the estimation of VMT, the EPA has issued guidance for VMT forecasting and tracking under Section 187 [20] for non-attainment areas and recommends the use of network-based travel demand modeling and the Federal Highway Administration's Highway Performance Monitoring System (HPMS). However, the HPMS, which uses traffic ground counts and centerline mileage as the underlying data for VMT estimates, is preferred over network-based travel demand modeling because the EPA recognizes that validated network models may not exist or are probably too resource intensive to be practical for annual VMT updates.

1.3 The Role of VMT Under the Intermodal Surface Transportation Efficiency Act (ISTEA) 1991

VMT estimates are most often employed as measures of effectiveness of transportation systems improvements and thus play an important role in modern transportation planning. Under Section 1025 of ISTEA 1991, in which statewide transportation planning is mandated, and Section 1008 relating to congestion and air quality mitigation, VMT estimates may be used as a performance measure in evaluating alternatives relating to systems improvements using travel demand models. For example, consider the use of an urban transportation modeling system to evaluate present and future travel within the road network of an urban area. Typical alternatives that may be considered may include changes to the modeled network to improve travel within the network. In this example, the alternative with the least system VMT for the urban area may be considered as a potential for development.

1.4 Background of Research

Vehicle miles traveled (VMT) is a function of both the number of trips made in a study area and the length of those trips. Two ten-mile trips contribute 20 vehicle-miles to the VMT total, as do ten two-mile trips. VMT totals are normally expressed in terms of total mileage travelled by vehicles either in twenty-four hour day -- normally referred to as Daily Vehicle-Miles of Travel (DVMT) -- or in a year -- referred to as Annual Vehicles Miles of Travel (AVMT). Because it is not possible to obtain travel data for every individual, various methods have been employed in VMT estimation to obtain the best possible estimate.

For several years, INDOT has desired an improved method of estimating the level of VMT in Indiana. With the passage of the 1990 Clean Air Act Amendments(CAAA), the need for reliable, well documented VMT estimation procedure(s) has become even more important. The VMT estimation method currently being used by INDOT is traffic count based, which follows closely the Highway Performance Monitoring System (HPMS) method. In the HPMS method, adjusted 24-hour traffic counts on a sample section are multiplied by the centerline mileage of the sample section to estimate the daily VMT for that section, which may then be annualized by multiplying the daily VMT by 365. The traffic data required by the HPMS for

VMT estimation in the State of Indiana based on the sampling requirements outlined in the HPMS Manuals consist of approximately 4,000 records. These records are based on sampling of links from functional classes found in the state highway system. The state highway system is comprised mainly of major highways, and does not include local roads. Also minor and urban collectors are not adequately represented on the state highway system (see Table 1.1). INDOT on the other hand has a complete inventory database of about 620,000 records of traffic data. Consequently, INDOT uses their superior inventory database as a basis for VMT calculations, while following closely the methods outlined in the 1987 HPMS Field Manual [6].

Even though INDOT has a superior inventory database, this covers only roads on the state highway system, which accounts for about 33 percent of the total state mileage (see Table 1.1), with the remaining 66 percent that are local roads neglected. It is noted in Table 1.1 that minor collectors and urban collectors are not well represented in the state road inventory, because these functional classes have less than one percent of the mileage on the state highway system. INDOT is thus uncomfortable with the statewide VMT estimates and the methods employed to estimate VMT on minor collectors, urban collectors, and local roads. In Section 187 of the 1990 CAAA [20] the EPA mentions that any "reasonable" method may be used to estimate VMT for functional classes such as local roads that are not accounted for by the HPMS VMT estimation method.

Table 1.1 What the State Road Inventory Contains [32].

FUNCTIONAL CLASS	FHWA CODE	PERCENT OF TOTAL STATE SYSTEM MILEAGE	PERCENT OF SYSTEM MILES ON STATE ROADS
Rural interstates	01	<1	100
Urban Interstates	11	<1	100
Urban expressways and freeways	12	<1	87
Other principal arterials rural	02	1	100
Other principal arterials urban	14	2	76
Rural minor arterials	06	3	100
Urban minor arterials	16	2	7
Rural major collectors	07	11	47
Minor collectors	08	11	<1
Urban collectors	17	2	<1
Percent total state roads system mileage of total state mileage		33	
Rural local roads	09	53	0
Urban local roads	19	13	0
Percent total local roads system mileage of total state mileage		66	

The accuracy of VMT estimates on local roads is critical for the estimation of auto emissions because local roads carry a majority of the "cold start" vehicle trips that contribute disproportionately to air pollution.

1.5 Purpose and Scope of the Research

This research aims at reviewing existing VMT estimation methods, placing emphasis on the INDOT and the Highway Performance Monitoring System (HPMS) methods. This is aimed at obtaining improved statewide VMT estimates for Indiana. The research will involve assessing the ability of these methods to produce statewide VMT estimates to satisfy the requirements of the Federal Highway Administration for VMT estimation by the HPMS, and those of the recently tightened Environmental Protection Agency (EPA) requirements in Section 187 [20] relating to VMT forecasting and tracking.

This research will focus on developing robust, simple, and cost-effective models to predict short-term VMT estimates that can supplement and, where necessary, replace the present estimates obtained from INDOT and HPMS methods, particularly VMT estimates for local roads that are not represented on the state highway system and whose traffic ground counts are not accounted for in the State Road Inventory. The models will be designed to minimize primary data collection needs, while maximizing the use of existing secondary data. The models developed in this study are simple and easy to use. This objective is met by providing a spreadsheet program written with macro facilities to implement the models.

The models and results obtained for this study are only applicable to Indiana, because they are based solely on data relating to Indiana. The use of the particular form of these models outside Indiana should be for comparison only and not for VMT estimation in any other state. However, procedures followed in the development of models in this study may be adopted for development of similar models for other states.

1.6 Implementation Benefits for this Research

Providing INDOT with a robust, simple and easy to use model will have several important uses, which include:

1. The models provide an independent source of statewide VMT estimates for comparison with the estimates obtained by the INDOT method.
2. The models provide INDOT with VMT estimates for functional classes such as minor collectors, urban collectors, and local roads which are neglected in the state road inventory.
3. The models enable INDOT to carry out sensitivity analyses leading to stable short-term VMT predictions and estimates of VMT growth rates that are obtained from VMT forecasts generated from the short-term model.
4. The VMT Tracking Model offers INDOT the opportunity to annually track their VMT forecasts obtained from the Short-term VMT Forecasting Model. The tracking of VMT

forecasts is required in Section 187 of the 1990 CAAA.

1.7 Thesis Organization

The results of this research will be presented in nine chapters. Chapter 1 provides an introduction to this study. Chapter 2 presents a general overview of the HPMS and a review of the literature on VMT estimation in general including the HPMS and INDOT VMT estimation methods. Chapter 3 presents an overview of the statewide VMT estimation models developed in this study, which includes discussions of assumptions supporting the models and comparison of the models with similar models developed in previous studies. Chapter 4 presents data organization for the development of statewide VMT forecasting models in this study. This involves discussions of reasons behind choosing FHWA's Highway Statistics and the Nationwide Personal Transportation Survey (NPTS) as primary sources of data for model development. Also discussed in Chapter 4 are the estimation of relevant parameters such as annual miles per licensed driver using data from the selected data sources -- Highway Statistics and NPTS. Chapter 5 presents discussions on statistical comparative tests on annual miles per licensed driver with respect to sex carried out toward efficient model construction. Chapter 6 presents the description of the Short-term VMT model developed in this study, including assumptions supporting the model, model calibration, model validation, and statewide VMT forecasts for the period 1990 through 1996 obtained using the

Short-term model. Chapter 7 presents a detailed description of the VMT Tracking model. Chapter 8 will discuss the QUATTRO PRO spreadsheet programs developed for use with the finished models. Chapter 9 presents the conclusions for this study and recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers two background topics: a general overview of FHWA's HPMS software, which is also EPA's preferred VMT estimation method under Section 187 [20], and a review of VMT estimation methods that have been proposed and used elsewhere. The review will entail an evaluation of each method of producing VMT estimates to meet the recently-imposed expectations of the 1990 Clean Air Act Amendments.

2.2 General Overview of the HPMS

This section presents a general overview of the HPMS, which is the VMT estimation method recommended by the FHWA and EPA. The general structure of the HPMS is discussed, including a detailed outline of the HPMS VMT estimation procedure and the shortcomings associated with the method.

2.2.1 Background of the HPMS

The HPMS is a nationwide inventory system of all the nation's public road mileage. This includes all facilities on and off the state highway systems. The system was developed and implemented by the FHWA in 1978 and has since been used by state highway agencies for the preparation of annual reports on the nation's highway system that are submitted to the FHWA. The annual HPMS reports are submitted either on tapes or diskettes before or on June 15 of each year [10]. The collection and reporting of the HPMS data have been the responsibility of the state highway agencies (SHA), local governments and the metropolitan organizations.

Since its implementation, the HPMS has been reassessed periodically in response to important highway issues and new legislative mandates and regulations. When the focus was on highway pavement management, the HPMS database was enhanced to expand and improve on processing pavement data. Currently, with clean air issues in focus, the HPMS is being used to monitor highway travel. The HPMS program is accompanied by a field manual to guide user agencies on data inputs and the annual report format requirements. The field manual has been updated five times since first issued in 1984 to meet the changing demands on the software. Presented in Table 2.1 are the updates of the HPMS field manuals.

These manuals contain specifications for the preparation of the various types of data collected and reported, with instructions for building and editing these data.

The HPMS database is used by various governmental and non-governmental institutions to evaluate the highway system in terms of its condition, performance and safety.

Table 2.1. The HPMS Field Manuals Issued by the FHWA

Date Issued	USDOT Code	Title
December 1, 1987	M 5600.1A	Highway
July 15, 1988	M 5600.1A Chg 1	Performance
April 15, 1989	M 5600.1A Chg 2	Monitoring
April 20, 1990	M 5600.1A Chg 3	System (HPMS)
February 24, 1993	M 5600.1A Chg 4	Field Manual

During the past two decades the FHWA has been using the HPMS in program administration decisions and currently, the EPA is using the HPMS-generated VMT estimates to monitor vehicle emissions.

2.2.2 The Structure of the HPMS Software

The HPMS consists of a module of programs used in preparing the annual HPMS reports. The module consists of a main driver program called FHWA HPMS, and seven dynamically called subprograms STHPMODU, STHPEDIT, STHPEXPF, STHPCALC, STHPSUMT, STHPBTAB, and STHPINTS. Each of these programs, including the main program, have been written in the COBOL programming language. The subprograms carry out various functions presented in detail in the 1987 HPMS Field Manual [6], which includes highway travel estimation and report generation.

2.2.3 Classification Systems in HPMS

All data collected and reported using HPMS are with respect to two major classification systems, namely, rural and urban systems prescribed by the FHWA. Presented in the following sections are brief descriptions of these classification systems including vehicle classification by vehicle type.

2.2.3.1 Rural-Urban Classification

The FHWA classification system is designed such that all highway facilities are classified with respect to their geographical location. The HPMS therefore handles data under two major geographical classification systems, namely, rural and urban systems, with the urban classification system subdivided into small and individualized urban systems. The urban and rural classifications are based on the population size which is presented as follows:

1. Roads located in areas with population less than 5,000 are classified as rural roads and highways.
2. Roads located in areas with population between 5,000 and 50,000 are classified as small urban roads and highways.
3. Roads located in areas with population of over 50,000 are classified as urbanized roads and highways.

By this classification system, highway facilities located in urban areas with populations less than 5,000 will be classified as rural.

2.2.3.2 Road Functional Classification System

The rural and urban functional systems currently being used in reporting data on roadways are presented in Table 2.2 and Table 2.3. These tables show the FHWA rural and urban functional classification systems, respectively.

Table 2.2. FHWA Rural Functional Systems [11]

Rural Functional Systems	
Code	Principal Arterial System
01	Interstate System
02	Other Principal Arterial
06	Minor Arterial System Collector System
07	Major Collector
08	Minor Collector
09	Local System

Table 2.3. FHWA Urban Functional Systems [11]

Urban Functional Systems	
Code	Principal Arterial System
11	Interstate System
12	Other Freeways and Expressways
14	Other Principal Arterial
16	Minor Arterial System
17	Collector System
19	Local System

2.2.3.3 Vehicle Classification

Under the FHWA classification system, vehicles are classified into 13 types. The vehicle classifications are presented as follows:

1. Motorcycles
2. Passenger car
3. Other two-axle, four Tire, single-unit vehicles.
4. Buses
5. Two-axle, six-tire, single-unit trucks
6. Three-axle single-unit trucks
7. Four or more axle, single-unit trucks
8. Four or less axle, single unit trucks
9. Five-axle, single unit trucks
10. Six or more axle, single unit trucks
11. Five or less, multi-trailer trucks
12. Six-axle multi-trailer trucks
13. Seven-or-more axle, multi-trailer trucks.

Traffic data collected and reported using HPMS are with respect to these vehicle classifications. The detailed definitions of these vehicle types are available in the 1993 HPMS Field Manual [10].

2.2.4 Input and Output Data Requirements for HPMS

The program requires three major types of data -- universe data, areawide data, and sample section data -- with respect to the classification systems in Section 2.2.3. These types of data are briefly described in the following sections.

2.2.4.1 Universe Data

Universe data consist of a comprehensive statewide inventory of public road mileage expressed in miles or kilometers by functional system, jurisdiction, geographic location (rural, small urban, and urbanized areas). These data are expected to reflect all mileage open to traffic as public roads and proposed roads that are part of approved or adopted plans.

2.2.4.2 Areawide Data

Areawide data are reported annually for rural, small urban and individualized urban areas for the respective roadway functional classifications. Much of the areawide data are obtained from the universe and sample section data.

2.2.4.3 Sample Section Data

Sample section data are obtained from roadway sample sections that represent a group or stratum of roads formed from the universe functional classification system. The groups are formed such that they are homogenous with respect to geometric design characteristics and traffic volume. Thus roads with similar traffic volumes within a predetermined range specified in the HPMS field manuals will belong to the same group (stratum). The groups (strata) are then sampled. The sampling plan, which is fully described in the 1987 HPMS Field Manual [6], is designed to be in concert with FHWA's 1985 Traffic Monitoring Guide [5].

The sampling process involves the random selection of sample sections to represent the groups (strata) of roadways formed, having determined the sample size required for each group formed. The procedures for the determination of sample sizes for a group of roadways are described in Appendix G of the 1987 HPMS Field Manual [6]. For VMT estimation, HPMS requires average annual daily traffic and roadway centerline mileage to generate the sample section, areawide, and universe daily VMT reports for the various road functional classification systems as required by the FHWA. The HPMS sample traffic data for Indiana are based on the sampling of links from each functional class of roads in the state highway system and consist of approximately 4,000 records [37].

2.2.5 Proposed Modifications to HPMS Data

The EPA's recent interest in HPMS travel data has prompted the need for certain changes to be made to the HPMS to meet both the FHWA and EPA requirements. The changes presented in the 1993 HPMS Field Manual [10] include the redefinition of urban boundaries to conform with the FHWA's federal aid boundaries and EPA's non-attainment areas boundaries. Non-attainment areas are areas that do not meet National Ambient Air Quality Standards (NAAQS) under the 1990 Clean Air Act Amendments. These areas may consist of some combination of individualized and small urban areas. The HPMS was initially developed by the FHWA to estimate VMT to conform with the FHWA federal aid boundaries only. Another important change presented in the 1993 Field Manual is the estimation of VMT for urbanized areas with populations of 200,000 and above. The EPA's need for this information has prompted the modification of the HPMS. Previous versions of HPMS were not designed to generate this information.

2.3 Review of VMT Estimation Methods

In this study, VMT estimation methods are classified into two broad divisions, namely, traffic count based and non-traffic count based methods.

Non-traffic count based VMT estimation methods, as the name suggests, involve the use of non-traffic data such as socioeconomic data for the estimation of VMT. Some of these non-traffic data include data on fuel sales, trip making behavior, household size, household income, population numbers, number of licensed drivers, and employment. Because most of these data are expensive to collect on regular basis, rough updates of old data are often used for the estimation of VMT. The accuracy of the input data into any VMT estimation method determines the accuracy of VMT estimates generated. Accurate input data are expected to produce accurate VMT estimates. VMT estimates based on non-traffic data are usually thought of as preliminary estimates, because the non-traffic data are often rough updates that are very likely to be inaccurate. In addition, VMT estimates based on non-traffic count data are associated with problems relating to

VMT distribution between residents and non-residents of a study area. For example, VMT estimates for a study area based on fuel sales attract questions such as "Was all the fuel sold in the study area used for travel in the study area only?" Such questions are difficult to answer with the information currently available. Attempts to address such issues often lead to making gross assumptions such as *travel into study area is equal to travel out of study area*. Because of the problems mentioned above associated with the use of non-traffic data for VMT estimation, estimates obtained from these methods are considered as rough estimates or at best as supplements to traffic count based VMT estimates which are known to be better estimates [20].

Traffic count-based VMT estimation method is currently the most preferred method because it is based on actual data on vehicle movement. The principle underlying this VMT estimation method is simple. For example, the VMT on a road segment is simply the product of the traffic volume -- usually the average annual daily traffic on the road segment -- and its center line mileage (equation 2.1).

$$DVMT_{ijk}=AADT_{ijk}*(CLM)_{ijk} \quad \text{...........(2.1)}$$

where

$DVMT_{ijk}$ is the VMT estimate on road segment i in functional class j located in a study area k.

$AADT_{ijk}$ is the average annual daily traffic on road segment i in functional class j located in a study area k.

CLM_{ijk} is the centerline mileage for road segment i in functional class j located in study area k.

For the ideal case, in which the average annual daily traffic for every road segment in a study area k is available, the VMT estimate for the study area is obtained by summing up the VMT estimate on all the roads in the study area following equation 2.2 presented below.

$$DVMT_k=\sum_i \sum_J DVMT_{ijk} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

where

$DVMT_k$ is the total VMT estimate for study area k.

$DVMT_{ijk}$ is the VMT estimate on road segment i in functional class j located in study area k.

The statewide VMT estimate is obtained by summing up the VMT estimates for all the study areas in the state or directly summing up the VMT estimates for all the roads in the state which may be obtained using equation 2.3.

$$DVMT_s=\sum_k DVMT_k \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

where

$DVMT_s$ is the statewide VMT estimate.

$DVMT_k$ is the total VMT estimate for the study area k.

The accuracy of traffic-count based VMT estimates is determined by the accuracy of the traffic data used for the estimation, assuming actual mileage of roads open to traffic is known. Where coverage counts are available for all roads in a study area, the VMT estimates obtained for the area will be the best possible estimate. This is a reality when dealing with a small road network. However, for huge road networks such as the Indiana State road network with approximately 92,000 center line miles of roads, it is not economical to obtain coverage counts for every road segment in the network. Coverage counts for such huge networks are obtained through a systematic stratified random sampling process recommended in the 1987 HPMS Field Manual [6]. The efficiency of the sampling process is dependent on the homogeneity of the road functional classes. Non-homogenous functional classes will ultimately lead to incorrect estimates of traffic volumes and VMT. Previous studies indicate that a roadway with complete access control can often carry three times the traffic handled by a non-controlled access street with identical lane width and number of lanes [30]. A classification system based on lane width and the number of lanes, for example, will lead to a non-homogenous classification system. Thus good functional classification systems that guide the formation of homogenous road functional classes are critical to the sampling process recommended in the HPMS Field Manuals.

In this study, the HPMS and INDOT VMT estimation methods are classified as traffic count-based and follow the VMT estimation method in the 1993 HPMS Field Manual [11]. The advantage of using traffic count based VMT estimation method versus the non-traffic count based method for VMT estimation in any study area is that there is no need to make assumptions about VMT allocation to residents and non-residents of the study area. This is because VMT estimates obtained for any road section include the vehicle miles travelled on that road by residents and non-residents of the study area.

In this study, two non-traffic count based VMT estimation models based on distribution and travel behavior of licensed drivers are developed. The models are supported by readily available and relatively cheap data. The models developed in this study are calibrated using traffic count based VMT estimates obtained from Highway Statistics, so that VMT forecasts generated from the models can be converted to traffic count based VMT estimates with respect to the various functional classes in the state. This VMT forecasting procedure is compatible with EPA's requirements for VMT forecasting. The EPA prefers VMT forecasts to be traffic count based [20].

2.3.1 The HPMS VMT Estimation Method

The HPMS method of VMT estimation involves the use of adjusted 24-hour traffic counts -- referred to as annual average daily traffic (AADT) -- obtained on sample sections identified through a systematic stratified random sampling process described in Section 2.2.4.3. The sample section VMT is estimated by the product of the section AADT and road segment mileage. The sample section VMT is expanded using expansion factors to obtain the areawide and universe VMT estimates. The HPMS VMT estimation method is preferred to other VMT estimation procedures currently available, because of the following advantages:

1. HPMS VMT estimates are based on actual data on vehicle movement on a road segment and the centerline miles of the segment. Using this method for VMT estimation in any study area eliminates problems associated with travel estimation in and out of the study area, or the allocation of VMT to residents and non-residents as may be the case using other methods.
2. Using the HPMS maximizes the use of current traffic monitoring programs and, thus, will result in lower cost than with most non-HPMS methods.
3. Traffic counts for HPMS are based on a sample design conforming to established statistical principles and well-documented standard procedures outlined in FHWA's 1985 Traffic Monitoring

Guide [5] and in the 1987 HPMS field Manual [6].

4. State highway agencies (SHA), local governments and the metropolitan organizations have been involved in the use of HPMS since its implementation in 1978 and are therefore familiar with the procedures involved in the operation of the database. The HPMS is supported by the FHWA and the state agencies and organizations using it. The HPMS has been modified to focus on VMT estimation to meet current requirements of the EPA.

5. There is an existing field monitoring process in place, in which FHWA staff conduct a review of the traffic data to ensure that procedures are followed. Flaws in the process may be detected and corrections made to the collection procedures for future years.

2.3.1.1 The HPMS VMT Calculation Processes

The VMT calculation process is carried out by SELSUMT, a subprogram of the HPMS submittal software, that calculates by functional system the vehicle miles travelled in a 24 hour period referred to as the daily vehicle miles traveled (DVMT). The HPMS VMT estimates are obtained by multiplying the sample section count-based AADT and the section length. To extrapolate sample section VMT estimates to represent the entire universe and areawide functional subsystems, the sample section VMT estimates are multiplied by expansion factors. The expansion factors are obtained by dividing the total mileage in the stratum by the mileage included in that stratum's sample following equation 2.4. An outline of the steps for the calculation of the expansion factors can be found in Appendix H of the 1987 HPMS Field Manual [6]. The computerized procedure incorporated in the HPMS software for calculating expansion factors is the SELEXPF option, which generates a summary table of expansion factors by volume group within each functional system and geographical area classification. For example, calculation of expansion factors for various volume groups classified under any of the road functional classification systems follows equation 2.4.

$$EF=TMVG/TMSSVG \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

where

EF is the expansion factor for the group sampled in a functional class.

TMVG is the total mileage in volume group sampled in a functional class.

TMSSVG Represents total mileage in sample sections in volume group.

2.3.1.2 Sample Section HPMS VMT Calculation

The VMT calculation process for sample sections is carried out by SELSUMT. SELSMUT is a subprogram of the HPMS submittal software, that calculates by functional system for each sample section the vehicle miles travelled in a 24 hour period as the daily vehicle miles traveled (DVMT). Equation 2.1 is used to obtain the HPMS sample section VMT estimate.

2.3.1.3 Areawide HPMS VMT Calculation

Having obtained VMT estimates for sample sections using equation 2.1, expansion factors are employed to transform or extrapolate the sample section data to obtain VMT estimates to represent areas such as the NAAQS non-attainment areas for the respective functional classification system and geographical area. The areawide VMT estimate is obtained using equation 2.5.

$$DVMT_{mj}=\sum_{i}\sum_{k}DVMT_{ijk}*EF_{ij} \quad \ldots\ldots\ldots\ldots\ldots (2.5)$$

where

$DVMT_{mj}$ is the VMT estimate for functional class j in area m.

$DVMT_{ijk}$ is the VMT for sample section k in group i belonging to functional class j.

EF_{ij} is the expansion factor for group i in functional classification j.

2.3.1.4 Universe HPMS VMT Calculation

Having VMT estimates for sample sections using equation 2.1, expansion factors are employed to transform or extrapolate the sample section data and VMT estimates, to represent each functional class and geographical area.

Equation 2.6 below is used to estimate the Universe VMT.

$$DVMT_j=\sum_i\sum_k DVMT_{ijk}*EF_{ij} \ldots\ldots\ldots\ldots\ldots(2.6)$$

where

$DVMT_j$ is the Universe VMT estimate for functional class j, which is the same as the statewide total for j functional class

$DVMT_{ijk}$ is the VMT for sample section k in group i in functional class j.

EF_{ij} is the expansion factor for group i in functional classification j.

2.3.1.5 <u>HPMS Statewide VMT Estimate Calculation</u>

The HPMS statewide VMT estimation is calculated using equation 2.7.

$$DVMT_s=\sum_i\sum_J\sum_k DVMT_{ijk}*EF_{ij} \ldots\ldots\ldots\ldots\ldots(2.7)$$

where

$DVMT_s$ is the statewide VMT estimate for functional class j

$DVMT_{ijk}$ is the VMT for sample section k in group i of functional class j.

EF_{ij} is the expansion factor for group i in functional classification j.

The units of DVMT are daily miles travelled, in thousands. DVMTs are estimated separately for rural, small urban and individual urbanized areas for each functional system. The current HPMS VMT report formats are available in the 1993 HPMS Field Manual [16].

2.3.1.6 Sources of Error and Shortcomings of the HPMS VMT Estimation Method

Even though HPMS is considered generally as the most sound and objective among the list of VMT estimation methods currently in use, user organizations consider this method impractical, due mainly to its input data requirements [1]. The HPMS input data for VMT estimation include traffic count data and centerline mileage of all roads in the state. The information on centerline mileage for all roads in the state is available; however, information on traffic counts is available for some roads sampled from the state network to represent the network as much as possible. The accuracy of VMT estimates produced by the HPMS method is therefore dependent on how well the sample sections represent the state network. The sampling process recommended in the HPMS for the collection traffic data requires pre-knowledge of the traffic data on all of roads in the state network. This information, which is used for the determination of the number of sample sections to represent a road network, is not completely available now at INDOT. Thus the stratification for sampling is based on non-volume data elements which may not necessarily produce groups or strata of roads with similar traffic volumes. Although recent studies have shown that stratification of roads is possible with the sampling of non-volume data elements [23], these studies did not indicate the degree of error associated with the use of non-volume data for stratification of traffic data into homogenous groups. This situation may lead to traffic data collected not being representative of the total system of roads and hence may lead to errors in the VMT estimates generated.

A second shortcoming of the HPMS is that VMT estimates generated by the HPMS are not representative of the system total because they do not include VMT estimates for local roads. VMT on local roads is an important parameter required by the EPA. The HPMS is designed to concentrate on federal aid roads only, with no provision for local roads [10] with respect to data collection and VMT estimation. In Indiana, local roads form about two-thirds of the state road network and carry approximately 10 to 20 percent of the total state VMT. Using HPMS for the statewide VMT will result in underestimation of the statewide VMT.

A third shortcoming of the HPMS is that it does not generate VMT estimates to meet EPA's current requirements such as the generation of VMT for areas not meeting the National Ambient Air Quality Standards (NAAQS) and travel information on urbanized areas with populations of 200,000 required for the SIP mobile source inventory. The HPMS, as initially developed by the FHWA, was not intended to produce this type of detailed information.

Finally, some potential sources of errors associated with the HPMS include biases related to the selection of sites for counting programs, incomplete traffic counts, and failure to count on the prescribed schedule.

In spite of these shortcomings and potential sources of error, the HPMS VMT estimation procedure is sound and objective. The proposed modifications to the HPMS method [20] will generate better information to meet the necessary requirements of the FHWA and EPA. Recent modifications to the HPMS still do not provide for VMT estimation for local roads. In the 1993 HPMS Manual, it is stated that VMT estimation for local roads may be obtained by any "reasonable method". In this study, a VMT estimation procedure is developed to generate VMT estimates for local roads, minor collectors, and urban collectors, which are unaccounted for by recently revised HPMS VMT estimation method.

2.3.2 The INDOT VMT Estimation Method

Due to reasons stated in Section 2.3.1.6 concerning the errors and shortcomings associated with the HPMS, INDOT does not use the HPMS for VMT estimation. Like the HPMS VMT estimation method, the INDOT VMT estimation procedure is traffic count based and follows the VMT estimation method outlined in the HPMS field manual [6, 10]. With traffic data being a critical factor affecting the accuracy of VMT estimated using traffic count data, INDOT's inventory database, which holds about 620,000 records of traffic data, is used for the estimation of VMT. The INDOT VMT estimates are therefore bound to be more accurate than that obtained from the HPMS, which is based on about 4000 records.

2.3.2.1 <u>The INDOT VMT Calculation Processes</u>

The INDOT VMT estimation procedure is described in the following sections using an example in seven steps.

Suppose DVMT is to be estimated for a study area with a total of z functional classes of roads. Suppose also that road i belongs to functional class j, which consists of m routes in all, k of which are sampled and m-k unsampled. Assume that AADT information is available for all the k sampled roads. Suppose that road i has 80 percent of its total length sampled with n sample sections, and also that road i is a member of the k sampled roads in functional class j. The estimation of DVMT using the INDOT method for road i, functional class j, and the subject study area as a whole is described in the following steps.

<u>Step 1</u>

This step involves the estimation of DVMT for individual sample sections and the total DVMT for the 80 percent of the road i that was sampled. The individual sample sections DVMT is estimated as the product of AADT and the centerline mileage of the sample section using equation 2.8. Assume sample section a is one of the n sample sections of road i. The DVMT for sample section a is obtained using equation 2.8.

$$DVMT_a = AADT_a * (CLM)_a \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.8)$$

where

$DVMT_a$ is the DVMT estimate for the sample section a of road i in functional class j.

$AADT_a$ is the adjusted 24-hour count on sample section a of road i in functional class j.

CLM_a is the centerline mileage for sample section a of road i in functional class j.

The total DVMT for the n sample sections of road i representing 80 percent of road i in length is estimated by summing up the DVMTs of the n sample sections using equation 2.9.

$$DVMT_{si} = \sum_{a=1}^{n} DVMT_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.9)$$

where

$DVMT_{si}$ is the DVMT estimate for all sample sections of road i in functional class j.

$DVMT_a$ is the DVMT estimate for the sample section a of road i in functional class j.

<u>Step 2</u>

This step involves the estimation of DVMT for the 20 percent of route i that was not sampled. This estimate is obtained from the product of the average DVMT per mile and the total centerline mileage for the unsampled 20 percent. The average DVMT per mile is obtained from the total DVMT for the sampled 80 percent of route i divided by the total mileage of sample sections. This is obtained using equation 2.10.

$$DVMT_{avgi}=DVMT_{si}/\left(\sum_{a=1}^{n} CLM_a\right) \quad \ldots\ldots\ldots\ldots(2.10)$$

where

$DVMT_{avgi}$ is the DVMT per mile estimate for the sample sections forming 80 percent of road i in functional class j.

CLM_a is the centerline mileage for sample section a of road i in functional class j.

$DVMT_{si}$ is the DVMT for all sample sections forming 80 percent of road i in functional class j.

The DVMT estimate for the 20 percent of roads in route i that are not sampled is obtained using equation 2.11.

$$DVMT_{ui}=DVMT_{avgi}*(CLM_{ui}) \quad \ldots\ldots\ldots\ldots(2.11)$$

where

$DVMT_{ui}$ is the DVMT estimate for all unsampled sections forming 20 percent of road i in functional class j.

$DVMT_{avgi}$ is the DVMT per mile estimate for the sample sections forming 80 percent of road i in functional class j.

CLM_{ui} is the total centerline mileage for all the 20 percent unsampled sections of road i in functional class j.

Step 3

The total DVMT estimate for route i is obtained in this by summing the DVMT estimates for the 80 percent sampled sections and the unsampled 20 percent of route i, this is obtained using equation 2.12.

$$DVMT_{rti}=DVMT_{ui}+DVMT_{si} \quad \ldots\ldots\ldots\ldots\ldots (2.12)$$

where

$DVMT_{rti}$ is the DVMT estimate for route i in functional class j.

$DVMT_{si}$ is the DVMT estimate for all sample sections forming 80 percent of road i in functional class j.

$DVMT_{ui}$ is the DVMT estimate for all unsampled sections forming 20 percent of road i in functional class j.

Step 4

This step shows the methods for the estimation of DVMT and DVMT per mile for the k sampled roads in functional class j for the study area.

The DVMT estimates for all k sampled roads are obtained from summing up the DVMT estimate for these roads using equation 2.13.

$$DVMT_{sj}=\sum_{b=1}^{k} DVMT_{sbj} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.13)$$

where

$DVMT_{sj}$ is the DVMT estimate for all k sample roads in functional class j.

$DVMT_{sbj}$ is the DVMT estimate for sample section b of road i in functional class j.

The DVMT per mile estimates for the k sampled roads in functional class j are obtained from the total DVMT for the sampled sections divided by the centerline mileage of these sample sections using equation 2.14.

$$DVMT_{avgj} = \left(\sum_{i=1}^{k} DVMT_{si} \right) / \left(\sum_{i=1}^{k} CLM_{si} \right) \quad ....(2.14)$$

where

$DVMT_{avgj}$ is the DVMT per mile estimate for the sample sections of the k roads in functional class j.

$DVMT_{si}$ is the DVMT estimate for all sample sections on road i in functional class j.

CLM_{si} is the total centerline mileage for sample sections on roads in functional class j.

Step 5

The DVMT estimation method for the m-k unsampled roads in functional class j is presented in this step. The DVMT for each unsampled road is estimated first, followed by the estimation of the total DVMT estimate for all m-k roads. Suppose a road c is a member of the m-k roads. The DVMT estimates for this unsampled road c in functional class j is obtained from the product of average DVMT per mile for functional class j and the centerline mileage of the unsampled road using equation 2.15.

$$DVMT_{uc}=DVMT_{avgi}*(CLM_{uc}) \quad \ldots\ldots\ldots\ldots\ldots (2.15)$$

where

$DVMT_{uc}$ is the DVMT estimate the unsampled road c in functional class j.

$DVMT_{avgj}$ is the DVMT per mile estimate for the sample sections of the k roads in functional class j.

CLM_{uc} is the centerline mileage for unsampled road c in functional class j.

The DVMT estimates for all m-k sampled roads in functional class j is obtained by summing up the DVMT estimate for these roads using equation 2.16.

$$DVMT_{uj}=\sum_{c=1}^{m-k} DVMT_{ucj} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.16)$$

where

$DVMT_{uj}$ is the DVMT estimate for all m-k unsampled roads in functional class j.

$DVMT_{ucj}$ is the DVMT estimate the unsampled road c in functional class j.

<u>Step 6</u>

This step outlines the DVMT estimation method for all roads in functional class j that consists of sampled and unsampled roads. The DVMT estimate for all roads in functional class j is the sum of DVMTs for the sampled and unsampled roads, this is obtained using equation 2.17.

$$DVMT_j = DVMT_{uj} + DVMT_{sj} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.17)$$

where

$DVMT_j$ is the DVMT estimate for all roads in functional class j.

$DVMT_{sj}$ is the DVMT estimate for all k sample roads in functional class j.

$DVMT_{uj}$ is the DVMT estimate for all m-k unsampled roads in functional class j.

Step 7

Assuming the DVMT have been estimated for all z functional classes in the study area, then the total DVMT for the study area which is the sum of DVMT of all the z functional classes is obtained using equation 2.18.

$$DVMT_{sa} = \sum_{j=1}^{z} DVMT_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.18)$$

where

$DVMT_{sa}$ is the DVMT estimate for all classes of roads in the subject study area.

$DVMT_j$ is the DVMT estimate for all roads in functional class j.

The INDOT VMT estimation method presented above is very flexible and easy to implement, such that VMT estimates can be generated for any study area once the necessary traffic data are available and the boundaries and the road network of the study area are established.

2.3.2.2 Sources of Error and Shortcomings Of the INDOT VMT Estimation Method

As with the HPMS method, potential sources of error associated with the INDOT method include biases related to the selection of sites for counting programs, incomplete traffic counts, and failure to count on a prescribed schedule. However, all these errors are avoidable.

The major source of error associated with the INDOT method is due mainly to insufficient traffic data or its unavailability for some functional classes of roads, such as minor collectors, urban collectors, and local roads. The contents of the state road inventory shown in Table 1.1 reveals that less than 1 percent of the total mileage of minor rural collectors and urban collectors are sampled with no sampling for local roads. These functional classes are neglected because they are not part of the state road system. Roads belonging to the state highway system are the only roads sampled, and local roads are not sampled because they are not part of the state highway system. The traffic data for minor rural collectors and urban collectors in the state road inventory are obviously not representative of the population of these functional classes, considering that minor rural collectors and urban collectors carry a wide range of traffic volumes. Using such limited information to estimate DVMT for the minor rural collectors and urban collectors in Indiana obviously leads to inaccurate DVMT estimates for these roads.

2.3.3 The Highway/Transit Network Models Based VMT Estimation Method

This method involves the use of highway/transit travel simulation models for regional traffic projections and for forecasting link volumes. From these traffic forecasts, VMT estimates are obtained from the product of the forecasted link volumes and the respective centerline mileage of the link. Highway/transit simulation models have been widely used for over 20 years for traffic forecasting. The decade of the 1980s, however, brought about a tremendous increase in the use of micro-computer-based highway/transit travel simulation models (such as UTPS, TRANPLAN, MINUTP, TMODEL, EMME/2, and QRS II) for traffic forecasting and transportation planning, because of the increased availability and decreased cost of hardware and software [29]. Traffic forecasting using highway/transit travel simulation models is usually carried out in five major steps. The execution of the five steps varies from model to model.

1. The first step involves the geographic aggregation of land uses into homogenous traffic analysis zones.

2. The second step (trip generation) involves the use of trip generation models, which may be linear regression models or cross-classification models, to predict the number of trips produced by and attracted to each zone [28]. The number of trips produced by and attracted to each zone represents the total number of trips into and out of each zone. The trip generation models depend on socioeconomic parameters as predictor variables. These socioeconomic parameters include residential density, employment, household size, household incomes, household vehicle characteristics, and trip-making habits.

3. Trip distribution models are then employed to link the trip ends predicted by the trip generation models. This results in the prediction of origin-destination flows.

4. Modal split models are then used to predict the percentages of flow carried by the various modes available for travel between each origin and destination pair.

5. The final step (traffic assignment) involves the use of models to assign origin-destination flows for each mode on specific routes of travel through the network being modeled. The models are then calibrated to match the observed volumes before using the model to forecast link volumes.

After calibration, the network link volumes are forecasted using the relevant socioeconomic parameters for future years. Using the forecasted link volumes and the expected link centerline mileage, DVMT estimates are obtained using equation 2.19.

$$DVMT_{sa}=\sum_{i}[(LV_{i})*(LL_{i})] \quad \ldots\ldots\ldots\ldots\ldots(2.19)$$

where

$DVMT_{sa}$ is the DVMT estimate for the study area modeled.

LV_i AADT for link i in study area network.

LL_i is the centerline mileage for link i in study area network.

VMT estimates obtained by this method are generally reasonably accurate for models that are well calibrated with actual traffic data [1]. These models are known to be good tools, capable of forecasting the impacts of policy actions in the future. However, there are a number of problems associated with the use of highway/transit network models for VMT estimation. These are discussed in the following section.

2.3.3.1 Sources of Error and Shortcomings of The Highway/Transit Network Models Based VMT Estimation Methods.

A major source of error associated with the use of highway/transit network models is related to the accuracy of models used in the network models. These models which include trip generation and trip distribution models, which may not precisely represent travel characteristics of the specific area or region being modeled. Errors in trip generation models would lead to errors in forecasted link volumes and therefore errors in VMT estimates generated from these models.

Highway/transit network models are often limited in the number of road links that can be built into the network to represent the real world situation. Modeling a network to represent the exact real world situation is most often far from reality. Usually, for large study areas, there is a limit to the number of links that can be modeled, resulting in a modeled network biased toward major roads with the omission of most, if not all, minor links. This obviously renders the modeled links in the network not detailed enough to represent all roads in the actual network being modeled. A network model not representative of the real network would lead to overestimation of the network traffic volumes and hence VMT estimates generated using the modeled network.

Calibration of models in many areas, particularly areas that have not experienced significant growth, may not have been kept up to date, due to lack of the need to plan for new transportation facilities. This can significantly affect the generated trips and hence VMT estimates. Finally, demographic and trip making input data for these models are often only based on rough updates of older data [1]. The accuracy of the updating factors affects the accuracy of the VMT estimates.

2.3.4 VMT Estimation Based on Fuel Sales

VMT estimation based on fuel sales is believed to have been first used in 1957, however, there is no documentation of the actual VMT estimation procedure used in those times [4]. Early VMT submittal to FHWA in the 1970s were clearly gallonage based [4].

Fuel sales based VMT estimation method involves the use of information on retail gasoline and diesel fuel sales in dollars, unit price per gallon of fuel, and estimates of fleet fuel efficiency (mpg). The VMT estimates based on fuel sales is calculated using equation 2.20 [4]:

$$DVMT_{sa} = (RetSales) * (MPG) / (PPG) \quad .....(2.20)$$

where

$DVMT_{sa}$	is the DVMT estimate for the study area modeled.
RetSales	is the total retail sales of fuel in dollars for the subject study area.
PPG	is the average unit price per gallon of fuel.
MPG	is the fleet fuel efficiency

2.3.4.1 Sources of Error and Shortcomings of VMT Estimation Based on Fuel Sales

The errors associated with VMT estimation by this method are dependent on the accuracy of retail fuel sales data and the fleet fuel efficiency (mpg) figure used. The fleet fuel efficiency (mpg) is as impossible to measure directly as VMT itself. The use of vehicle manufacturers' figures may lead to serious errors, because this may not represent the system fleet fuel efficiency. Fleet fuel efficiency (mpg) for any area depends on the following factors:

1. Fleet age mix.
2. State of vehicle maintenance.
3. Topography and weather.
4. Local driving patterns (trip lengths) and habits.
5. Evaporation and spillage losses of fuel during sales and while in motion.

Since the above factors vary with location, the fleet fuel efficiency is intuitively expected to be a function of location.

Other sources of error include possible errors in the revenue statistics, which depend upon estimates of fuel sales and the fact that fuel purchased in one area may be used in another. With respect to data collection, a substantial amount of time is spent gathering the revenue statistics, which renders this method impractical.

With the introduction of new technology for powering automobiles, such as alcohol and electricity, forecasting VMT based on gasoline and diesel becomes more difficult, because it is not currently clear how acceptable such technology will be in the future. Thus, current fuel sales based VMT forecasts without factoring in such technologies will obviously be in error. Finally, forecasting the unit price of fuel is almost an impossible task because this depends on government policies and many other economic and political factors, which are difficult to predict.

VMT forecasts based on fuel sales should be used with caution because of the shortcomings of the method discussed above. These forecasts should always be considered as rough estimates that may be useful as preliminary estimates.

2.3.5 VMT Estimation Based on Odometer Recordings

The registration of some vehicles such trucks involve the recording of odometer values from one year to the next mainly for tax evaluation purposes [1]. The odometer values recorded are the actual miles traveled by trucks in each state which are reported by the truck operators. In the ideal case where odometer readings are available for all vehicles, the actual VMT may be obtained by summing up the odometer recording for all vehicles, assuming there are no errors associated with vehicle odometers.

2.3.5.1 Sources of Error and Shortcomings of VMT Estimation Based on Odometer Recordings.

VMT estimation using odometer readings is too resource intensive, probably the main reason why it is not used often. The method has a number of shortcomings associated with it, presented in the following section, which renders the method an impractical and unreliable method of estimating VMT.

The list of possible sources of errors include the following:

1. Odometer calibration errors due to worn out odometer cables.

2. Reporting errors

3. Second-party readings or transcription errors

4. Odometer rollovers

5. Odometer tampering

6. Vehicle drop out that may be due to accidents or aged vehicles.

7. Out-of-area travel likely to be considered as in-area travel.

2.3.6 VMT Estimation Based on Household and Driver Surveys

In 1969, 1977, 1983, and 1990 households were surveyed under the Nationwide Personal Transportation Survey (NPTS) to capture information on characteristics of personal travel, as well as data on all personal trips for all purposes and all modes of travel. Information from the 1969, 1977, and 1983 NPTS surveys were used to develop models to estimate household vehicle miles of travel on a national basis. The models were developed using data on the average miles driven by licensed drivers with respect to age and sex, and the distribution of the licensed drivers in the sample also with respect to age and sex [18,24]. VMT estimates are generated from these models from the product of the average miles driven and the population of licensed drivers with respect to age and sex.

Similar models have been developed for Indiana in this study improving upon the short comings of the previous models stated in the following section.

2.3.6.1 Sources of Error and Shortcomings of VMT Estimation Based on Household and Driver Surveys

The potential errors associated with these surveys is that data reported by household members to interviewing staff -- such as household vehicle annual mileage and annual vehicle miles driven -- by respondents may not be accurate. This is because people do not actually keep such records. However, the raw data obtained from the household interviews is edited to correct for some obvious errors. The editing process is available in the NPTS User's Manuals [15, 16, 17].

The NPTS surveys may not represent the distribution of licensed drivers, since the primary aim of the surveys was not to capture licensed drivers. The licensed drivers distribution may be biased. Using biased distributions of licensed drivers to develop models for VMT estimation may lead the generation of inaccurate VMT estimates by the biased models.

2.3.7 Comparison of VMT Estimates

VMT estimates derived from the methods discussed in this section have rarely been compared. This is because most of the organizations involved in VMT estimation either use the estimates internally or report the estimates to different

Federal organizations. In the case of two widely used methods -- the network based travel demand modeling and the HPMS -- the situation is the same. State DOTs have reported HPMS statistics to the FHWA, while MPOs have used VMT estimates generated from the models, primarily for the in-house assessment of impacts of system improvements. However, there are some ongoing efforts by INDOT and the MPOs in Indiana [36] to compare VMT estimates. Comparisons of VMT estimates will help evaluate the accuracy and the assumptions on which these estimates are based.

2.4 Chapter Summary

The principal focus behind this chapter is to present a review of the various VMT estimation methods that have been proposed and used elsewhere. The review is to guide researchers in developing a VMT estimation procedure in this study to supplement the statewide VMT estimates produced by the current INDOT and HPMS methods. It was revealed in the review process that the INDOT and HPMS VMT estimation procedures produce good estimates for functional classes well represented on the state highway system, and inaccurate estimates for roads not part of the state highway system. A statewide VMT estimation procedure is developed in this study that relies on non-traffic count based input data, based on the behavior of licensed drivers with respect to sex and age category. The statewide VMT estimates obtained from the procedure will supplement the traffic count based INDOT and

HPMS VMT estimates. The method will produce more accurate statewide VMT estimates for functional classes such as minor collectors, urban collectors, and local roads, which are neglected in the state road inventory and have with virtually no data in the database to be used for VMT estimation.

CHAPTER 3

AN OVERVIEW OF THE STATEWIDE VMT ESTIMATION MODELS DEVELOPED IN THIS STUDY

3.1 Introduction

Historically a number of factors have been identified as good predictors of highway travel, the major ones being population, number of licensed drivers, income, auto ownership, fuel consumption, and settlement patterns. Historical trends in these factors have tended to parallel the growth of highway travel [5]. In this study, two cross classification statewide VMT forecasting models -- Short-term model and VMT Forecasts Tracking Model -- are developed based on the distribution of licensed drivers in Indiana -- with respect to sex and predefined age groups -- and the average annual vehicle miles driven by the license drivers -- with respect to the predefined age groups and sex of the licensed drivers. The objective here is to obtain statewide VMT forecasts for Indiana from an alternative source to serve as supplementary VMT estimates for the traffic count-based VMT estimates obtained using the INDOT VMT estimation method. The models developed in this study are calibrated to estimate VMT for the road functional classes presented in Table 1.1.

A review of the INDOT VMT estimation method (see Section 2.3.2) showed that the INDOT method has the potential to generate accurate VMT estimates once the traffic data used for VMT estimation is representative of the traffic on the state road network. The review highlighted the fact that there are either no traffic data or insufficient traffic data available for some road functional classes (see Table 1.1) in the State Road Inventory. The undercounted functional classes are minor collectors and urban collectors. For rural and urban local roads there are no traffic data available currently in the State Road Inventory for use in estimating VMT. The INDOT VMT estimates obtained for these functional classes of roads are expected to be inaccurate, because of either insufficient or no traffic data in the State Road Inventory. The focus of this study is to provide INDOT with an independent source of statewide VMT estimates, such that statewide VMT estimates obtained from the final product of this study can be compared with that obtained from the INDOT VMT estimation procedure, while providing supplementary estimates for the functional classes with either no traffic data or insufficient traffic data. This chapter covers discussions on the following topics: a review of past research that involved the use of licensed driver-based VMT estimation models, an overview of the statewide VMT estimation model developed for this research, the assumptions supporting the model, and the desirable attributes of the model.

3.2 <u>Past Research that Involved the Use of Licensed Drivers Based VMT Estimation Models</u>

The model developed in this study is similar to the models developed by Maring in 1974 [18] and Greene [24] to forecast long-term national highway vehicle travel. The models developed by Maring and Greene were cross classification national VMT estimation models. Both researchers used the models to predict automobile and light truck VMT using demographic predictions of the population of licensed drivers, with respect to defined age groups and sex. Maring relied on the constancy of some demographic patterns -- such as the distribution of population and licensed drivers with respect to sex and age cohort -- and average annual miles traveled -- to predict highway vehicle travel as a function of demographic forecasts. The data used in the models included census estimates of population by age and NPTS results from 1969,1977, and 1983. In both studies NPTS data were used to determine annual VMT per driver, distribution of licensed drivers, and trends in VMT per driver. The models operate in the following way:

<u>Step 1</u>

Population for the forecast year, by age and sex is input.

<u>Step 2</u>

Based on NPTS trends, population is converted to licensed drivers.

Step 3

The number of licensed drivers is then multiplied by forecasts of annual automobile and light truck vehicle miles driven per licensed driver.

Step 4

Estimates of vehicle miles driven, at the level of sex and age cohorts, are added up to obtain the total forecast of annual miles driven, which were interpreted as vehicle miles traveled.

The method is implemented using the following simple equation.

$$AVMT=\sum_{i}\sum_{j}(P_{ij}*r_{ij}*a_{ij}) \quad \ldots\ldots\ldots\ldots\ldots(3.1)$$

where

AVMT is the total annual vehicle miles traveled for both sexes and all age cohorts,

P_{ij} is the population of sex i (men, women) and age cohort j,

r_{ij} is the rate of drivers licensed per capita for sex i (men, women) and age cohort j, and

a_{ij} is the annual miles per licensed driver for sex i (men, women) and age cohort j.

Both Greene and Maring noted variations in some parameters, such as average annual miles driven across the age cohort and with respect to sex used in their models. The cross classification models used in their study were designed to take care of these variations toward deriving good national

VMT estimates. Even though statistical hypothesis tests were not performed to confirm the noted variations, graphical representations of these parameters presented in their research -- such as average annual miles driven with respect to sex plotted against the age cohort -- showed clearly that average annual miles driven varied with respect to sex and age group [18,24].

It is important to mention here that the models used by Maring and Greene were designed to forecast highway travel with respect to household travel only, and not total highway vehicle travel. Greene, however, stated in his study that the highway travel forecasts obtained from his models were indicative of the order and growth of the total highway travel because total highway travel, is dominated by personal travel and because commercial traffic such as freight traffic is strongly correlated with passenger traffic. The philosophy underlying the Maring and Greene approaches was to reduce the description of the future state of the world to forecast highway vehicle travel to a minimum number of readily predictable variables [24]. Green stated in his research that demographic forecasts are likely to be robust and, if travel patterns selected for models do not vary significantly over time, highway vehicle travel forecasts are likely to be stable over time and under a wide range of conditions. To confirm the validity of this statement, Greene compared Maring's 1974 highway travel forecasts for 1984 to the "actual" figures. Greene found that the forecasts were only 7 percent lower than the "actual", despite wide fluctuations in fuel prices and economic growth, and even the failure of some key assumptions supporting Maring's model [24].

3.3 An Overview of the Statewide VMT Estimation Models Developed in this Study

Two cross classification statewide VMT estimation models -- Short-term VMT forecasting model and VMT Tracking model -- similar to those used by Maring and Greene are developed in this study. The models developed in this study is simple and has a number of desirable attributes that have been discussed in Section 3.5. The models, unlike those used in previous studies [18,24], predict the total vehicle miles driven by all licensed drivers for all vehicle types, using demographic predictions of the population of licensed drivers, age and sex. Based on the fact that a driver can drive only one vehicle at any time, the estimates of the total vehicle miles driven that are generated by the model are interpreted as VMT.

The idea is to begin with a stable forecast of the driving-age population and, on the basis of historical patterns and trends, license holding rates are assumed to predict the distribution of licensed drivers with respect to sex and age cohort. The licensed driver distribution forecasts, together with estimates of average annual miles per licensed driver, are used to obtain short-term VMT forecasts. Forecasts of driving-age population are usually considered stable because, as Maring [18] points out in his research, the percent driving-age population of total state population is particularly predictable 10 to 20 years ahead, because nearly all the persons of driving age will have already been born. The data used in the models included census estimates of population by age and NPTS results from 1977 and 1990. As in previous studies [18,24], NPTS data are used to estimate annual vehicle miles driven per licensed driver and the trends in vehicle miles driven per licensed driver. The distribution of licensed drivers, unlike in the Maring and Greene studies, was obtained from the FHWA publication Highway Statistics. The cross classification models developed in this study operates in the following way:

Step 1

The state population for the forecast year is input.

Step 2

Based on trends obtained from data on licensed drivers published in Highway Statistics, the state population is converted to the number of licensed drivers with respect to age and sex.

Step 3

The number of licensed drivers is then multiplied by forecasts of annual vehicle miles driven for all motorized vehicles per licensed driver.

Step 4

Estimates of vehicle miles driven with respect to sex and age cohorts are added up to obtain the total forecast of annual miles driven, which was interpreted as vehicle miles traveled.

The method is implemented using equation 3.1 in Section 3.2. The models is calibrated using traffic count-based VMT estimates for functional classes with adequate counts so as to generate VMT estimates for the various functional classes presented in Table 1.1. The end product is designed to increase the chances of making stable VMT forecasts. This is achieved by using predictor variables such as the distribution of licensed drivers in Indiana with respect to age cohort and sex that are published annually in FHWA's <u>Highway Statistics</u>. The published distribution of licensed drivers may be compared with that generated by the model, which may be a process of tracking the forecasting capabilities of the model developed in this research. Although the VMT estimation model employed in this research is similar to those of Greene and Maring, there are some fundamental differences between the models. The differences are presented in Section 3.3.1.

3.3.1 The Differences Between the Models Developed in This Research and Those in Previous Studies.

The fundamental differences between the models developed in this research and those of Greene and Maring are as follows:

1. The models developed in this study was based on two data sources, the NPTS and FHWA's <u>Highway Statistics</u>. The NPTS data for 1977 and 1990 were used for the estimation of average annual miles per licensed driver

with respect to sex and age cohort, and data on the distribution of licensed drivers also with respect to defined age and sex obtained from Highway Statistics. The models of Greene and Maring were based mainly on NPTS data for estimates of average annual miles driven per licensed driver and the distribution of licensed drivers. The reasons for using the FHWA's Highway Statistics data on the distribution of licensed drivers in place of the NPTS data for the model are (a) to enable the evaluation of the forecasting capabilities of the models annually, and (b) using the annually published licensed drivers distribution in Highway Statistics in the model directly will produce VMT estimates to track forecasts made for the year in question.

2.The VMT forecasts obtained from the Greene and Maring models were national -- United States --forecasts, while the models developed in this study forecasts VMT for Indiana.

3. The Greene and Maring VMT estimation models forecast highway travel with respect to automobile and light trucks only, not total highway VMT, which would include VMT for commercial vehicles. The models developed in this research forecasts total highway VMT, including VMT for commercial traffic.

4. While the model developed for this study is designed to forecast short-term and long-term VMT estimates, the Greene and Maring VMT estimation models were designed to

forecast long-term highway VMT only.

5. The model developed for this study is calibrated to generate traffic count VMT estimates for all the road functional classes presented in Table 1.1. The Greene and Maring VMT estimation models were not calibrated or designed to produce VMT estimates for road functional classes.

3.4 Assumptions Supporting the Statewide VMT Estimation Models Developed in This Study

The assumptions supporting the validity of the model developed in this study are as follows:

1. Highway and non-highway modal shares of passenger miles travelled will not change significantly in the short-term -- 1990 through 1996. Any significant change in non-highway travel may induce a change in the average miles driven by licensed drivers, which is one of the major predictor parameters in the models. For example, the introduction of high-speed intercity trains operating at attractive prices may cause a modal shift from highway travel and hence a significant reduction in the average miles driven by licensed drivers.

2. Average vehicle speeds and average travel time will not change significantly. The theory here is that average miles driven by licensed drivers is not only constrained by monetary resources but, more importantly, by the average time available for licensed drivers to travel.

Furthermore, the average time available for travel is dependent to some extent on the average speed of travel. Speed limits posted on highways are generally known to affect the average speed of vehicles traveling on the highway. Consequently, an increase in highway speeds limits may cause an increase in the average speed of vehicles on the highway. If the average travel time remains approximately constant as assumed, then the average miles driven by licensed drivers may increase. For this study, it is assumed that in the short term, if average speed of vehicles remains the same, then the average miles driven by licensed drivers will also remain constant. This assumption is subject to debate, the researchers of this study are of the opinion that the assumption is reasonable and should be appropriate for short-term VMT forecasting.

3. Vehicle load factors -- passengers per vehicle -- will not change significantly in the short term. Here changes in vehicle load factors may cause changes in vehicle miles of travel.

4. Average miles driven by Indiana licensed drivers on out-of-state roads and highways is equal to the average miles driven by out-of-state licensed drivers on Indiana roads and highways. This assumption is important in transforming the statewide VMT estimated by the model into statewide VMT based on traffic counts on the various roads and highways in the State of Indiana. This

assumption is relied upon for calibration of the model developed in this research to forecast statewide VMT for the various road functional classes in the state network. The VMT estimates obtained from traffic counts are interpreted as VMT in the State of Indiana, irrespective of the state of residence of licensed drivers using the roads. The models are dependent on the distribution of licensed drivers in the state of Indiana, who are not the only drivers on Indiana roads, and who do not necessarily drive all their vehicle miles on Indiana roads. It is necessary to make this assumption in order to transform vehicle miles driven by Indiana licensed drivers into statewide VMT in Indiana. This assumption is considered reasonable, because Indiana is an agricultural state and does not attract a lot of tourists like Florida and other states tourist attracting states. However, it is important mention here that the some major highways in Indiana do carry considerable through traffic. This may have an effect on the validity of this assumption stated in this section. However, there is not enough information available at the moment to evaluate the impact that the through traffic will have on the model's forecasting capabilities.

3.5 Desirable Attributes in the Statewide VMT Estimation Models Developed in This Study

The following are desirable attributes in the statewide VMT estimation models developed for this study:

1. The models, which are programmed into QUATTRO PRO Spreadsheets, are simple and easy to use. The results are easy to interpret and understand.

2. The models are considered efficient because it requires very limited data -- either the total Indiana population or the total number of Indiana licensed drivers -- to forecast statewide VMT. The efficiency of any forecasting model or procedure is based to a large extent on the amount of data required to develop, calibrate and apply it.

3. The models are easy to monitor and update. Because of the simplicity of the structure of these models, the models can be updated easily and quickly, based on new information. The Indiana licensed drivers distribution, published annually in the FHWA's Highway Statistics, can be used to monitor the licensed drivers estimates generated by the models with respect to age and sex. It is therefore possible to monitor the performance of the short-term VMT forecasting model by tracking annually, forecasts of licensed drivers distribution by age and sex. The availability of such information on a periodic basis will provide the

opportunity to examine the validity of the assumptions supporting the model. The EPA lays emphasis on the tracking of VMT forecasts [20]. Also, future Nationwide Personal Transportation Surveys provide an opportunity to update the estimates for the average annual miles driven with respect to age and sex. The next NPTS is scheduled for 1995 [35], and the data on average miles driven by licensed drivers are expected to capture any changes in annual miles driven by licensed drivers due to changes in the state network. Changes in the state network, either due to construction of new links in the network, or rehabilitation activities to improve performance of links in the network, may cause drivers to choose alternative routes and hence cause changes in annual miles driven by licensed drivers.

4. The models provide INDOT with a useful tool for forecasting stable short-term and long-term statewide VMT, based on stable forecasts of the predictor variables. These forecasts, which depend on stable predictor variables such as the proportion of licensed drivers of the driving age population with respect to age and sex, can be estimated with reasonable accuracy for the next 15 years, because all potential drivers within this time period have already been born. Therefore based on historical and current trends and future assumptions

about the predictor variables, stable short-term statewide VMT forecasts are obtained using the models developed in this study.

3.6 Chapter Summary

This chapter has presented a general overview of the two statewide cross classification models developed in this study -- a short-term VMT model and a VMT tracking model -- assumptions supporting the models, desirable attributes in the models, and the relationships between the models developed in this study and similar models developed by Maring and Greene in past research.

CHAPTER 4

DATA ORGANIZATION FOR MODEL DEVELOPMENT

4.1 Introduction

This chapter covers discussions on the data sources relied upon for the construction of the statewide VMT estimation models developed in this study.

The sources of data used for model construction may affect the accuracy of the results generated by the model. Models built with poor quality data from unreliable sources are more likely to generate poor quality results. Therefore careful selection of data sources for model construction is important. The selection criterion should include the accuracy and reliability of data from the source and the ability of the source to provide new data periodically to be used to update and monitor the model's performance, if necessary. The data sources selected for this study, which are the NPTS and FHWA's Highway Statistics, were based on these criteria. Also discussed in this chapter are some problems encountered with the use of NPTS Public Use Tapes in this study.

4.2 Data Sources Used for Model Development

The model is based on data from two sources, namely the FHWA's Highway Statistics and the Nationwide Personal Transportation Surveys (NPTS) [15, 16, 17]. Indiana data on the distribution of licensed drivers and traffic count-based VMT estimates from Highway Statistics were used for the construction and calibration of models developed in this study respectively. Both national and Indiana NPTS data for 1990 and 1977 on annual miles driven per licensed driver were used to estimate the average annual miles driven per licensed driver with respect to sex.

4.2.1 The FHWA's Highway Statistics Data

Highway Statistics, which has been published annually beginning with the year 1945, contains statistics of general interest, including VMT, motor fuel consumed annually, driver licensing, highway user tax, state highway finance, federal aid for highways, highway mileage, characteristics and performance. Most of the information published in Highway Statistics is with respect to the 50 states and the District of Columbia. The statistics relevant to this research in Highway Statistics are the number of Indiana licensed drivers with respect to sex and age, and traffic count-based VMT estimates for all the functional classes in Indiana presented in Table 1.1. The distributions of licensed drivers for Indiana, published for the years 1990 and 1991 in Tables 4.2 and 4.3, respectively, were used in the construction of the statewide VMT forecasting models in this study, and trends in licensed driver registration in Indiana in the years 1965 through 1991 -- in Table 6.3 -- were used to forecast statewide VMT. Statewide traffic count-based VMT estimates for functional classes in the state with adequate traffic counts in the state road inventory for the years 1990, 1991, and 1992 -- in Table 6.8 -- were used for the calibration of the models. The reasons for adopting data on the distribution of licensed drivers from Highway Statistics for this study include the fact that these data represent the actual distribution of all licensed drivers in Indiana. Secondly, Highway Statistics is published annually, thus annual publications of licensed drivers distributions and traffic count-based VMT estimates may be used to track the distributions of licensed drivers and VMT forecasts derived from the models. With the EPA now concerned with the tracking of VMT forecasts [20], the VMT tracking model -- one of the models developed in this study -- will enable INDOT to track VMT forecasts obtained from the short-term VMT forecasting model -- the second model. Data published annually in Highway Statistics will be useful for the evaluation of the performance and efficiency of the model as a VMT and licensed drivers forecasting tool annually. To enable direct use of data on the licensed drivers distribution published in Highway Statistics, the age groups adopted for the model developed for this study are similar to those published in Highway Statistics. The only difference is the consolidation of certain age groups. The groups of licensed drivers of ages 75 and above are collapsed into one group, while in Highway Statistics, the number of licensed drivers with ages 85 and above are considered as one group (see Table 4.1). This was done to obtain distribution factors for all age groups in the model, because there are no numbers published for licensed drivers in the age groups of 80 to 84 (80-84) and 85 and over in the 1990 and 1991 Highway Statistics.

4.2.2 The Nationwide Personal Transportation Survey Data

The Nationwide Personal Transportation Surveys (NPTS) are household surveys carried out with the main objective of providing information to assist transportation planners and the public in general in need of comprehensive data on travel and transportation patterns in the United States.

The NPTS surveys compile national data on the characteristics of personal travel, which include the annual miles driven per licensed driver in all motorized vehicles. These data were used in this study to estimate the average miles driven per licensed driver with respect to age and sex. The geographic coverage of the NPTS includes all 50 states and the District of Columbia. The households interviewed in the NPTS surveys are based on samples obtained from the national population such that they were representative of the national and regional distribution of households. Toward obtaining representative regional samples in the NPTS, the United States is divided into nine regions [15, 16, 17].

Table 4.1 Age Groups used in Models.

Highway Statistics Age Groups	Model Age Groups
16-19	16-19
20-24	20-24
25-29	25-29
30-34	30-34
35-39	35-39
40-44	40-44
45-49	45-49
50-54	50-54
55-59	55-59
60-64	60-64
65-69	65-69
70-74	70-74
75-79	75 and over years
80-84	
85 and over years	

All households in the sample were interviewed using the same standard questionnaires. The major sponsor of NPTS surveys is the USDOT's FHWA. The first of these surveys was carried out in 1969, followed by updates in the years 1977, 1983, and 1990. The 1990 NPTS is the most recent of these surveys.

The 1990 NPTS procedures differed in some ways from the procedures used in 1969, 1977, and 1983. The differences are described in the <u>1990 NPTS User's Guide for the Public Use Tapes</u>, in which it is stated that efforts were made to maintain compatibility across the NPTS surveys [15]. The differences in the survey procedures have been studied and would not have any significant adverse effect on the data

Table 4.2 The 1990 distribution of Indiana licensed drivers by age and sex [12].

Age Group	Number of Licensed Drivers in Indiana	
	Males	Females
16-19	103,639	92,948
20-24	179,807	165,042
25-29	227,451	213,490
30-34	232,295	218,259
35-39	206,830	194,307
40-44	177,977	170,912
45-49	134,699	128,636
50-54	109,767	105,039
55-59	97,208	93,387
60-64	99,020	95,138
65-69	93,382	91,394
70-74	73,286	73,623
75+	114,646	109,172
Total	1,850,007	1,751,347
Overall State Total		3,601,354
Percent of State Total (%)	51	49

Table 4.3 The 1991 distribution of Indiana licensed drivers by sex and age [11].

Age Group	Number of Licensed Drivers in Indiana	
	Males	Females
16-19	92,094	83,085
20-24	171,522	157,940
25-29	209,298	197,006
30-34	222,370	209,878
35-39	201,599	189,443
40-44	172,977	166,260
45-49	134,190	128,078
50-54	106,911	102,700
55-59	91,722	88,797
60-64	91,584	88,620
65-69	87,241	86,258
70-74	71,885	72,169
75+	116,923	112,636
Total	1,770,316	1,682,870
Overall State Total		3,453,186
Percent of State Total (%)	51	49

adopted for use in this study.

Two major differences worth mentioning here are:

1. The NPTS data reported for the 1969, 1977, and 1983 were different from that of 1990 NPTS data such that NPTS data made available for public use for the years 1969, 1977, and 1983 were with respect to the nation as a whole. Before 1990, no information was provided at state level, while for the 1990 NPTS, information is provided at the state level.

2. The number of completed household interviews in the four surveys varies significantly, as presented in Table 4.4.

Table 4.4 Number of completed households NPTS interviews [15].

NPTS Year	Number of Completed Household Interviews
1969	15,000
1977	18,000
1983	6,500
1990	22,317

Detailed information on each NPTS, with respect to its financing, household sampling and interviewing procedures, is available in the User's Guide for the Public Tapes.

The data most relevant to this study that were taken from these surveys are the total miles driven in the past 12 months with respect to the age groups defined in Table 4.1. To capture these data, members of sampled households who are licensed drivers were asked the following question, "About how many miles did you personally drive during the past 12 months? Please include mileage driven in all motorized vehicles". This question was presented in slightly different forms for all the NPTS surveys, but with the same meaning and therefore captured the same information. The responses to these questions are interpreted as the vehicle-miles driven by the licensed driver interviewed for all motorized vehicles he has driven in the past 12 months. Data on the total miles driven in the past 12 months for two surveys (1977 and 1990) were used for this study. Estimates of average annual miles driven obtained from the 1990 NPTS are used for the development of the models. The average annual miles estimates obtained from the 1977 NPTS data were used for statistical analyses toward the possibility of using national data on annual miles per licensed driver at the national level for development of a long-term statewide VMT model for Indiana. This is necessary because there are no specific data on Indiana in any previous NPTS that could be used for estimation of growth rates for annual miles driven per licensed driver. The advantage of using NPTS data in this study is that future NPTS data provide an opportunity to update the 1990 estimates of average annual miles driven with respect to age and sex, as well as providing information for the evaluation of assumptions supporting the models. The next NPTS is scheduled for 1995 [35].

4.3 The Estimation of Mean Annual Miles Driven with Respect to Model Age Groups and Sex

The 1977 NPTS data files on the Public Use Tape and the 1990 NPTS data (on compact disk) presented in Tables 4.5 and 4.6 were identified. The files used in this study are marked "**".

Table 4.5 Files on the 1977 Public Use Tape [17].

File Number	Files Identifications on the 1977 Public Use Tapes
1	Household Characteristics
2	Household Members and Their Characteristics **
3	Household Vehicle Information
4	Worker Occupation and Travel to Work Data **
5	Travel Day Trip Data
6	14-Day Travel Period Trip Data
7	Stop Data for 14-Day Travel Periods Trips
8	Annual Long Trip Data from the National Travel Survey (NTS) for the 13,365 households common to both NPTS and NTS.

Table 4.6 Files on the 1990 NPTS Public Use Tapes [15].

File Number	Files Identifications on the 1990 NPTS Compact Disk
1	Household File **
2	Person File **
3	Vehicle File
4	Travel Day trip File
5	Travel Period Trip File

4.3.1 The Estimation of Average Annual Miles Driven Using The 1990 NPTS Data

The estimates of average annual miles driven by Indiana licensed drivers were used for the construction of the two models developed in this study. The reasons for using the 1990 NPTS data for construction of the models include the following:

1. The 1990 NPTS is the most the recent survey and provides travel data on Indiana licensed drivers. The 1990 NPTS data has similar data on all fifty states and the District of Columbia. Such detailed information was not provided in the public use files available for previous NPTS surveys -- 1969, 1977, and 1983. Because the focus of this study is on Indiana, the use of the 1990 NPTS is considered appropriate.
2. Calibrated statewide VMT estimating models with 1990 as base year for forecasting statewide VMT is consistent with EPA recommendations for using 1990 traffic count-based VMT estimates as base year estimates for VMT forecasting discussed in Section 187 of the 1990 CAAA [20].

To obtain the average miles driven by Indiana licensed drivers with respect to the thirteen age groups (see Table 4.1) and sex, a SAS program was written to call the two files marked "**" in Table 4.6. The two files are the "Person" file and the "Household" file. The Household file contains data at the household level for households interviewed in the survey. Each household is assigned a unique number, which is also represented in the other files in Table 4.6. The Person file contains data for each household member, such as sex, age, person identifying number, household identifying number, and annual miles driven. The relevant data are retrieved from the two files and merged, then the average annual miles driven are estimated using the merged files. The data manipulation process is executed by a SAS program specially coded for data manipulation of the 1990 NPTS files. The sequence in which the SAS program is executed is illustrated in the following steps.

Step 1

Call the Household file and extract household-identifying numbers for Indiana from the national sample.

In the 1990 NPTS Manual [15], the following two variables:

1. household-identifying ID number (HOUSEID), and
2. state FIPS code (HHSTFIPS)

were used to identify Indiana households surveyed in the 1990 NPTS. FIPS codes are unique numbers -- a state identifying code -- assigned to each state and the District of Columbia [15]. The State FIPS code for Indiana is 18. The SAS program reads the Household file and extracts all HOUSEID corresponding to HHSTFIPS of 18. The output for this section of the program indicated that there are 1,328 Indiana households in the 1990 NPTS sample.

Step 2

Call the Person file and extract specific household member's data such as identifying number, age, sex, dummy variable for licensed driver, and the total miles driven in the past 12 months if respondent is a licensed driver. In this step, the program calls the Person file and reads the following variables from the file:

3. Household-identifying ID number (HOUSEID),
4. Is respondent a licensed driver? (LIC_DRVR),
5. Age of household reference person (REF_AGE),
6. Sex of household reference person (REF_SEX), and
7. Total miles driven in the past 12 months (YEARMILE).

The data obtained from the Person file at this stage is the information on all residents in each household interviewed in the national sample.

Step 3

Merge the data extracted from the Household and Person files in Step 1 and Step 2 using the household identifying number (HOUSEID). The objective in this step is to reduce household person data obtained in Step 2 at the national level to data on Indiana. To achieve this objective, the program is written to merge the Indiana household identifying numbers (HOUSEID) obtained in Step 1 with the household identifying numbers (HOUSEID) obtained in Step 2 -- national data. Household identifying numbers (HOUSEID) obtained in Step 2 that are different from those obtained for Indiana in

Step 1 are deleted from the national sample at this stage. The output from this step are the following Indiana household person data:

1. Household identifying numbers (HOUSEID).
2. Dummy variable for respondent being a licensed driver (LIC_DRVR) (LIC_DRVR=01) [15].
3. Age of household reference person (REF_AGE).
4. Dummy variable for sex of household reference person (REF_SEX) (Male=01 and Female=02) [15].
5. Total miles driven in the past 12 months (YEARMILE).

The output obtained from this step is saved to a file for further processing in Step 4.

Step 4

Process data on licensed drivers in Indiana identified by a dummy variable with value of 1 [15]. All data on household persons who are not licensed drivers are deleted at this stage from the data set created in Step 3, by deleting all cases with LIC_DRVR not equal to 1. Next, group Indiana licensed drivers with respect to sex, which is achieved by using the REF_SEX variable with REF_SEX= 1 for males and REF_SEX=2 for females. Table 4.7 shows the distribution of males and females in the 1990 NPTS sample for Indiana and the nation, respectively, by driving age (16 years and over) and licensed drivers.

Table 4.7 Number of males and females in the 1990 NPTS sample for Indiana and the nation.

Driving Age (16 years and over) Distribution in Sample			
	Total	Males	Females
United States	39,661	18,432	22,229
Indiana	2,260	1,014	1,246
Licensed Drivers Distribution in Sample			
United States	35,145	17,033	18,112
Indiana	2,065	994	1,071

The percentages of males and females in the 1990 NPTS sample for Indiana and the United States respectively, according to driving age (16 years and over) and licensed drivers are presented in Table 4.8.

Table 4.8 Percent of total licensed drivers by sex for Indiana and nation, in the 1990 NPTS sample based on Table 4.7.

Driving Age (16 years and over) Distribution in Sample			
	Total	Males	Females
United States (%)	100	46.5	53.5
Indiana (%)	100	44.9	55.1
Licensed Drivers Distribution in Sample			
United States (%)	100	48.5	51.5
Indiana (%)	100	48.1	51.9

<u>Step 5</u>

Using the PROC MEANS option in SAS, the average annual miles driven for the past 12 months by licensed drivers in the sample for Indiana -- with respect to the thirteen age groups

-- are obtained. The output from the program includes the number of observations and standard deviation for the respective age groups and sex defined for model. A summary of the SAS program output on average annual miles driven, number of observations in each age group used for the calculation of the average annual miles driven, and the standard deviation of the average miles driven are presented in Tables 4.9 and 4.10 for Indiana male and female licensed drivers, respectively.

It is important to mention here that household licensed drivers with the following YEARMILE values were deleted from the merged data obtained in Step 1 and Step 2 before the average annual miles driven was calculated for each age group:

1. 999994 = Legitimate Skip,
2. 999998 = Not Ascertained,
3. 999999 = Refused.

These values are not estimates of annual miles driven by licensed drivers reported by respondents; they are dummy variables assigned to licensed drivers who legitimately skipped the question relating to the YEARMILE variable (999994), in situations in which the YEARMILE value could be not ascertained (999998), and in situations in which the YEARMILE was refused (999999).

Step 6

To obtain the average miles driven by licensed drivers in the nation in the 1990 NPTS data, only Step 2 and Step 5 presented above are processed.

Table 4.9 Summary of average annual miles driven by male licensed drivers in Indiana based on the 1990 NPTS sample.

Age Group	Number of Observations	Average Annual Miles Driven	Standard Deviation
16-19	33	12,733	12,411
20-24	90	18,236	18,050
25-29	131	20,082	13,974
30-34	101	20,754	21,613
35-39	105	16,236	22,669
40-44	73	19,712	12,139
45-49	54	18,916	16,590
50-54	54	18,685	14,361
55-59	43	17,729	18,381
60-64	41	15,522	16,067
65-69	48	14,656	14,565
70-74	21	9,500	9,500
75 and over	34	8,286	8,480

A summary of the SAS program output on average annual miles driven, number of observations, and the standard deviation of the average miles driven are presented in Tables 4.11 and 4.12 for national male and female licensed drivers, respectively.

Discussions on the estimates of annual miles driven and corresponding standard deviations for the thirteen age groups, obtained from the 1990 NPTS and presented in Tables 4.9 through 4.12, is presented in Section 5.2 -- in Chapter 5 -- which deals with the comparison of annual miles driven per licensed driver with respect to sex age.

Table 4.10 Summary of average annual miles driven by female licensed drivers in Indiana based on the 1990 NPTS sample.

Age Group	Number of Observations	Average Annual Miles Driven	Standard Deviation
16-19	44	9,580	10,643
20-24	105	12,985	11,883
25-29	115	12,026	12,548
30-34	131	10,574	8,260
35-39	98	11,002	12,539
40-44	72	10,100	9,938
45-49	53	7,928	6,534
50-54	50	8,549	7,056
55-59	54	7,057	6,878
60-64	45	5,366	4,796
65-69	42	4,783	5,010
70-74	38	3,416	3,987
75 and over	32	4,237	4,299

Table 4.11 Summary of average annual miles driven by male licensed drivers in the nation based on the 1990 NPTS sample.

Age Group	Number of Observations	Average Annual Miles Driven	Standard Deviation
16-19	825	9,612	14,546
20-24	1,343	16,873	18,064
25-29	1,774	18,659	17,793
30-34	1,826	19,374	20,745
35-39	1,784	18,668	16,971
40-44	1,600	19,171	18,924
45-49	1,227	18,812	18,402
50-54	980	18,261	18,927
55-59	899	16,696	17,300
60-64	818	13,658	12,732
65-69	788	10,853	9,947
70-74	524	9,576	11,023
75 and over	595	6,869	7,056

Table 4.12 Summary of average annual miles driven by female licensed drivers in the nation based on the 1990 NPTS sample.

Age Group	Number of Observations	Average Annual Miles Driven	Standard Deviation
16-19	728	6,633	9,822
20-24	1,384	11,648	14,179
25-29	1,764	11,247	10,543
30-34	1,910	10,730	11,638
35-39	1,809	11,312	11,812
40-44	1,619	10,782	11,451
45-49	1,127	9,793	8,853
50-54	963	8,644	8,803
55-59	867	7,705	7,427
60-64	764	6,550	7,055
65-69	706	5,551	8,471
70-74	520	4,603	5,739
75 and over	505	3,316	4,672

4.3.2 The Estimation of Mean Annual Miles Driven Using The 1977 NPTS Data

The 1977 NPTS data for public use was designed to provide information at the regional level only, thus, there is no information on Indiana or any state specifically. 1977 NPTS data on annual miles driven in the past 12 months in all vehicles -- including commercial vehicles -- are used in statistical tests carried out in this study to investigate the possibility of using national data on annual miles driven in the in the estimate growth rates for the development of a long-term statewide VMT model for Indiana, since previous NPTS data did not contain specific data on Indiana. To obtain the average miles driven by licensed drivers in the nation with respect to sex and the age groups defined for the construction of the model, a SAS program was written to call the two files marked "**" in Table 4.5. The two files namely, "Household Members and Their Characteristics" file and "Worker Occupation and Travel to Work Data" file, hereafter referred to as "File 2" and "File 4" respectively. The SAS program is coded to extract the relevant data for use in estimating average annual miles driven from the two files and then merging the data obtained from the two files. Using the PROC MEANS option in SAS and the merged data from File 2 and File 4, estimates of average miles driven with respect to sex and the thirteen age groups defined for the models developed in this study are obtained at the national level. The sequence in which the SAS program is executed is illustrated in the following steps.

<u>Step 1</u>

Call File 2, which contains information on the households members interviewed in this survey. This file contains various data on household characteristics, which include data for the following variables relevant to this study:

1. Household serial number (HOUSEID),
2. Household member line number (PERSONID),
3. Age (REF_AGE), and
4. Sex (REF_SEX).

The variable names as coded in the SAS program are in parentheses. These variables are consistent with the variables used in Section 4.3.1 Step 2. The SAS program read data for the variables listed above from File 2.

Step 2

Call File 4 and extract a specific household person's data, such as identifying number, age, sex, dummy variable for licensed driver, and the total miles driven in the past 12 months, if the respondent is a licensed driver.

In this step, File 4 is called, and data for the following variables listed below are read from the file:

5. Household serial number (HOUSEID),
6. Household member line number (PERSONID),
7. Licensed Driver (LIC_DRVR), and
8. Annual miles driven (YEARMILE).

The variable names in the parentheses are the names used in the SAS program so that all variables are defined the same in the SAS programs developed to process the 1990 NPTS files and data. The item descriptions on the left of the parentheses are the same as presented in the 1977 NPTS Public Tape User's Manual [17]. The household serial numbers and the household member line numbers are the same in File 2 and File 4.

Step 3

Merge the data extracted from File 2 and File 4 in Step 1 and Step 2 using the household identifying number (HOUSEID) and household member line number (PERSONID). The objective in this step is to put together the necessary data on licensed drivers from the two files so as to obtain the necessary data to estimate average annual miles driven with respect to the defined age groups and sex. To achieve this objective, the program is written to merge the household identifying numbers (HOUSEID) and household member line number (PERSONID) obtained in Step 1 with the household identifying numbers (HOUSEID) and household member line numbers (PERSONID) obtained in Step 2. The output from this section of the program, which has all the relevant data on licensed drivers to estimate the average annual miles driven, has the following variables:

1. Household serial number (HOUSEID),
2. Household member line number (PERSONID),
3. Age (REF_AGE), and
4. Sex (REF_SEX).
7. Licensed Driver (LIC_DRVR), and
8. Annual miles driven (YEARMILE).

The Household serial number (HOUSEID) and the Household member line number 1 (PERSONID) called in Step 1 are the same as those called in Step 2. The output obtained from this step is saved to a file for further processing.

<u>Step 4</u>

Process data on licensed drivers in the nation. Licensed drivers are identified by the dummy variable 1 [<u>17</u>]. All data on household persons who are not licensed drivers are deleted at this stage from the data set created in Step 3, by deleting data for respondents the LIC_DRVR variable not equal to 1. The LIC_DRVR variable is set equal to 1 if a household member is a licensed driver. The next process in the SAS program is the separation of data on licensed drivers with respect to sex. This is carried out by relying on the variable assigned to gender -- REF_SEX= 1 for males and REF_SEX=2 for females.

Step 5

Using the PROC MEANS option, estimates of average annual miles driven for the past 12 months by the licensed drivers in the sample for the nation with respect to the thirteen age groups presented in Table 4.1 were obtained. The output from the program includes the number of observations and standard deviation for the respective defined model age groups and sex. The summary of the results in the output from the program on the average annual miles driven, number of observations in each age group used for the calculation of the average annual miles driven, and the standard deviation of the average miles driven are presented in Tables 4.13 and 4.14 for nation's male and female licensed drivers, respectively.

Discussions on the estimates of annual miles driven and corresponding standard deviations for the thirteen age groups, obtained from the 1977 NPTS and presented in Tables 4.13 and 4.14, is presented in Section 5.2 -- in Chapter 5 -- which deals with the comparison of annual miles driven per licensed driver with respect to sex age.

Table 4.13 Summary of average annual miles driven by male licensed drivers in the nation based on the 1977 NPTS sample.

Age Group	Number of Observations	Average Annual Miles Driven	Standard Deviation
16-19	274	6,800	9,170
20-24	375	14,612	15,335
25-29	411	15,697	15,068
30-34	364	17,567	16,802
35-39	278	20,536	25,009
40-44	231	16,540	13,747
45-49	236	15,718	13,460
50-54	266	14,008	9,735
55-59	228	14,290	17,420
60-64	206	9,433	7,909
65-69	148	8,160	6,973
70-74	116	6,773	5,490
75 and over	104	5,063	4,793

Table 4.14 Summary average annual miles driven by female licensed drivers in the nation based on the 1977 NPTS sample.

Age Group	Number of Observations	Average Annual Miles Driven	Standard Deviation
16-19	250	3,947	5,837
20-24	386	6,498	6,206
25-29	415	7,142	10,260
30-34	351	7,031	6,812
35-39	274	7,279	7,687
40-44	250	6,348	5,336
45-49	226	6,683	6,145
50-54	242	6,360	5,309
55-59	188	5,168	4,658
60-64	164	4,619	5,262
65-69	94	3,788	3,425
70-74	76	3,060	2,413
75 and over	46	2,653	2,510

4.4 Problems Encountered with the NPTS Public Use Tapes Procured For Use in This Study

This section presents the problems encountered with the use of the NPTS Public Use Tapes procured from the FHWA for use in this study. Three NPTS Public Use Data which are, the 1990 NPTS Data(on compact disk), the 1983 NPTS Data (on 9-track tape), and the 1977 NPTS Data (on 9-track tape) were procured for use in this study. But due to problems associated with loading the 1977 and 1983 NPTS onto the UNIX system of the Engineering Computer Network (ECN) at Purdue University, only the 1990 NPTS was success-fully loaded. The 1977 NPTS was loaded onto the network after several attempts.

However, the files on the tape mixed up and not in the order expected (as presented in the 1977 NPTS Manual). The procedures used to identify the various files on the 1977 Tape are discussed in this section. There were several unsuccessful attempts to load 1983 NPTS Tape onto the ECN, so the 1983 NPTS could not be used in this study. Several telephone calls were made to Barbara Eversole [35] in relation to problems faced with loading the 1977 and 1983 NPTS Public Use Tapes. Barbara Eversole is responsible for providing assistance with the use of the NPTS Tapes and, with her help, the 1977 NPTS Tape was loaded onto the ECN, but the loaded files were found to be in an order different from the expected in the User's Guide for the 1977 NPTS Public Use Tapes. Several attempts were made to load the files to obtain them in the right order with no success. It was not possible to load the 1983 NPTS Tape onto the network due to its incompatibility with the ECN. Several attempts to load the 1983 NPTS Tape were unsuccessful. Barbara Eversole stated in one of the telephone communications with her that she has had similar calls from other researchers concerning the use of the 1977 and 1983 NPTS Tapes. She further stated that the 1977 and 1983 tapes have not been given much attention in the past because they have not been used in the past as they are being used these days. Below is presented discussion of the problems faced with the 1977 and 1983 NPTS Tapes in this study.

The 1977 NPTS Public Use Tape

The 1977 NPTS Public Use Tape procured from FHWA for use in this study is a 9-track tape with data on the tape in EBCEDIC format -- a standard format for presenting data for use with various computer languages and programs. There are 8 files on the Tape shown in Table 4.5, and the files relevant to this study being Files 2 and 4 -- marked "**" in the Table. It was possible to load the tape onto the ECN, but the major problem faced was that the files loaded on the network ended up on the network in an order different from that indicated in the 1977 NPTS User's Guide for Public Tapes [17], so that the files could not be identified. It was therefore not possible to identify the two files needed for this study after loading the 1977 NPTS Tape following the instructions in the User's Manual. There were several unsuccessful attempts by the ECN Site Consultant Stacey Clark to load the files -- a process that went on for three months. A different approach was adopted to locate the two files needed for this study from the eight mixed up files. This involved the coding of two separate SAS programs to identify the each of the two files from the eight files in the wrong order by relying on some dummy variable located in specific columns in the respective files -- see the variables in Tables 4.15 and 4.16. To identify the two files, the SAS programs were run with the eight files and the output checked to verify if the variable expected in a particular column is present.

Table 4.15 The variables and their location in File 2 used in a SAS program coded for the identification of File 2 [17].

Variables used in identifying File 2*		
Location in file (columns)	Variable	Expected Values
1 - 6	Household serial number (HOUSEID)	000001 - 306218
22 - 23	Household member line number (PERSONID)	1 - 25
25	Age (REF_AGE)	1 - 99 000 - less than 1
34	Sex (REF_SEX)	1 - Male 2 - Female

* File 2 - "Household Members and Their Characteristics" --See Table 4.5

Table 4.16 The variables and their location in File 4 used in a SAS program coded for the identification of File 4 [17].

Variables used in identifying File 4+		
Location in file (columns)	Variable	Expected Values
1 - 6	Household serial number (HOUSEID)	000001-306218
22 - 23	Household member line number (PERSONID)	1-25
89 - 90	Licensed Driver (LIC_DRVR)	01 - Yes 02 - No Blank - Not Applicable
92 - 98	Annual Miles Driven (YEARMILE)	0 - 999999 999999 - No Answer Blank - Not Applicable

+File 4 - "Worker Occupation and Travel to Work Data" file --See Table 4.5

For example, in File 2, the dummy variable for sex REF_SEX is expected in column 31 with R_SEX=1 for male and R_Sex=2 for female, thus in File in column 31 only 1 and 2 are expected, thus any file containing numbers other than 1 and 2 for REF_SEX in this column for each observation is discarded. The program was used to identify File 2 and the other variables used to confirm that the File identified was the right file -- File 2. The same idea was used to identify File 4 in the remaining seven mixed files. The dummy variable LIC_DRVR for identifying licensed drivers was used -- see Table 4.16. The second SAS program was thus coded to retrieve the relevant variables -- in Table 4.16 -- expected to be found in File 4 in specific columns. The SAS program was run using the remaining seven files until the right file -- File 4 -- was located. Having located File 2 and File 4, the variables HOUSEID and PERSONID, which were common to both files, were inspected to verify that the two files were the right files. For example, a HOUSEID was selected and the PERSONID noted in File 2, then in File 4, the selected HOUSEID was located and the corresponding PERSONID verified.

The 1983 NPTS Public Use Tape

The 1983 NPTS Public Use Tape procured from FHWA for use in this study is a 9-track tape with data on the tape in SAS format -- a standard format for presenting data for use with various computer languages and programs. As mentioned earlier, it was impossible to load the 1983 NPTS Tape on the

ECN network. There were several unsuccessful attempts by the ECN Site Consultant Stacey Clark to load the files onto the network. Most times there were many files created, each containing one or two lines, which was not related in any way to the data expected in the files on the 1983 NPTS Tape. In one attempt, the five files expected on the tapes were obtained, but the contents were a combination of numbers and alphabets for each line or observation, which were not the expected contents of the files, which were supposed to be numbers only. Having tried all possible ways to load the tape to obtain the expected files without success for almost five months, the plans to use the 1983 NPTS Tape in this study was abandoned due to time constraints on the project. The 1983 NPTS data which are travel data at the national level, was intended to be used in estimating growth rates for annual miles per licensed driver for the long-term statewide VMT model. But results of statistical tests performed in Chapter 5 of this document to verify the similarity in annual miles driven per licensed driver for the nation and Indiana to enable national growth rates to be used in the long-term statewide VMT model. However, results of the statistical test performed in Chapter 5 of this document did not seem to support the use of national growth rates for the development of the long-term statewide VMT model intended for this study. It should also be noted that the 1983 NPTS has no specific data on Indiana. The inability to read the 1983 NPTS Tape therefore has no major effect on the short-term models developed in this study and the results obtained in the study.

The 1990 NPTS Public Use Tape

The 1990 NPTS Public Use data used in this study from a compact disk was in ASCII format -- a standard format for presenting data for use with various computer languages and programs. No problems were encountered with the use of this 1990 NPTS on the compact disk.

4.5 Chapter Summary

This chapter covered discussions on the two major data sources, namely Highway Statistics and NPTS, selected for construction of the two models developed in this study, based on the fact that they provide accurate and reliable data periodically which could be used to update and monitor the models developed in this study. Also discussed were problems encountered with the use of the NPTS Tapes procured for use in this study, including discussions on some strategies adopted to solve some of the problems encountered.

CHAPTER 5

DATA ANALYSIS

5.1 Introduction

This chapter covers the statistical analysis of data obtained from the selected sources -- NPTS and *Highway Statistics* -- in Chapter 4 toward construction of an efficient statewide VMT forecasting models in this study. This includes statistical comparative testing of estimates of average annual miles driven with respect to sex and age at the state and national levels obtained in Chapter 4. Statistical non-parametric comparative tests concerning the similarity or difference in annual miles driven carried out for matched populations with respect to sex and age in this study are discussed. A typical example of a nonparametric comparative test carried out in this study is to test whether the annual miles driven by male and female licensed drivers matched with respect to age cohort are the same.

The results of such statistical comparative tests are important in determining the final structure of the cross classification statewide VMT estimation models developed in this study. Because, there are no data specific on Indiana in any previous NPTS, results of statistical tests will determine whether previous NPTS data at the national level could be used in the development of long-term statewide VMT model for Indiana. The estimation of the percent distribution of licensed drivers with respect to age cohort and sex used in the model for forecasting is presented in this chapter.

5.2 Comparison of Male and Female Licensed Drivers Estimates of Average Annual Miles Driven

To identify any variation in the average annual miles driven by male and female licensed drivers, histograms of average annual miles driven with respect to thirteen age groups are plotted in Figure 5.1 for Indiana and Figures 5.2 and 5.3 for the nation. Figure 5.1 is based on estimates of the average annual miles driven by Indiana male and female licensed drivers in Tables 4.9 and 4.10. Figure 5.2 is based on average annual miles driven estimates for male and female licensed drivers in the nation (Tables 4.11 and 4.12). Figure 5.3 is based on estimates of average annual miles driven for male and female licensed drivers in the nation in Table 4.13 and 4.14. The figures -- Figure 5.1, Figure 5.2, and Figures 5.3 -- show that, for all 13 age groups, estimates of average annual miles driven by males is always greater than those obtained for females. The three figures also indicate that the average miles driven irrespective of sex, by licensed drivers increases from the 16-19 age group, generally peaking around the 25-29 and 30-34 age groups, then decreasing toward the 75 years and over age group. This makes sense because, in general, males and females in the 25-29 and 30-34 age groups are the most active in society and are therefore expected to drive more miles compared to the other age groups.

As age increases from 35 toward 75 years and over, the Figures show decreases in average miles driven for male and female licensed drivers. In general, this may be attributed to the fact, that as licensed drivers approach age 75, they tend to make fewer trips and hence fewer miles.

The relatively low average annual miles driven by the 16-19 age group could be because many people in this age group do not own their own vehicles, relying on their parents' cars for transportation.

Finally, it is noted in Figure 5.1 that the average annual miles driven by male licensed drivers in the 35-39 age group is 16,236, which is found to be approximately 3,500 miles less the adjacent age groups. From trends in annual miles driven by male licensed drivers in Figures 5.2 and 5.3, the average annual miles driven by male licensed drivers in the 35-39 age group is expected to be between 20,754 miles and 19,712, miles which is the annual miles driven by male licensed drivers in the 30-34 and 40-44 age groups respectively -- see Table 4.9. The possible explanation for the relatively low mileage driven by licensed drivers in the 35-39 age group may be attributed to bias in sampling. Because previous NPTS data did not contain information specific to Indiana, it was not possible to investigate the relatively low mileage driven by licensed drivers in the 35-39 age group presented in Figure 5.1 and Table 4.9. Future NPTS data may help provide some explanation for this trend.

It is intended to use the growth rates of annual miles driven at the national level to represent growth rates for Indiana licensed drivers in the model if the annual miles driven by licensed drivers with respect to sex and age are statistically the same. The reason for this strategy is due to unavailability of data in the 1977 NPTS for Indiana to use in estimating of the growth rates. Histograms of average annual miles driven by licensed drivers for Indiana and the nation with respect to the thirteen age groups are plotted in Figures 5.4 and 5.5 for male and female licensed drivers, respectively. Figure 5.4 is based on estimates of average annual miles driven by male licensed drivers in Indiana and the nation that are presented in Tables 4.9 and 4.11, based on data from the 1990 NPTS public use files. Figure 5.5 is based on the estimates of the average annual miles driven by male licensed drivers in Indiana and the nation that are presented in Tables 4.10 and 4.12, based on data in the 1990 NPTS public use files.

From the plots in Figures 5.1 through 5.5, the following inferences were drawn:

1. Figures 5.1 through 5.3 show that, at both the state and national levels, it can be inferred that average annual miles driven by men for each age group is always greater than that of females in the same age group.

2. Comparing the average annual miles driven by licensed drivers of the same gender in Indiana and the nation in Figures 5.4 and 5.5, it can be inferred that the average annual miles driven by males in Indiana and in the nation do not seem to vary significantly for licensed drivers in the same age group. The same inference holds for the average miles driven by female drivers in Indiana and in the nation.

Even though plots in Figures 5.1 through 5.5 made it possible to draw some graphical inferences about the average annual miles driven by licensed drivers discussed above with respect to sex, age for Indiana and the nation, researchers verified these variations statistically by carrying out statistical comparative tests. The objective here is to carry out statistical comparative tests for the various cases presented in the plots -- Figures 5.1 through 5.5 -- to confirm the inferences drawn from the histograms in this section.

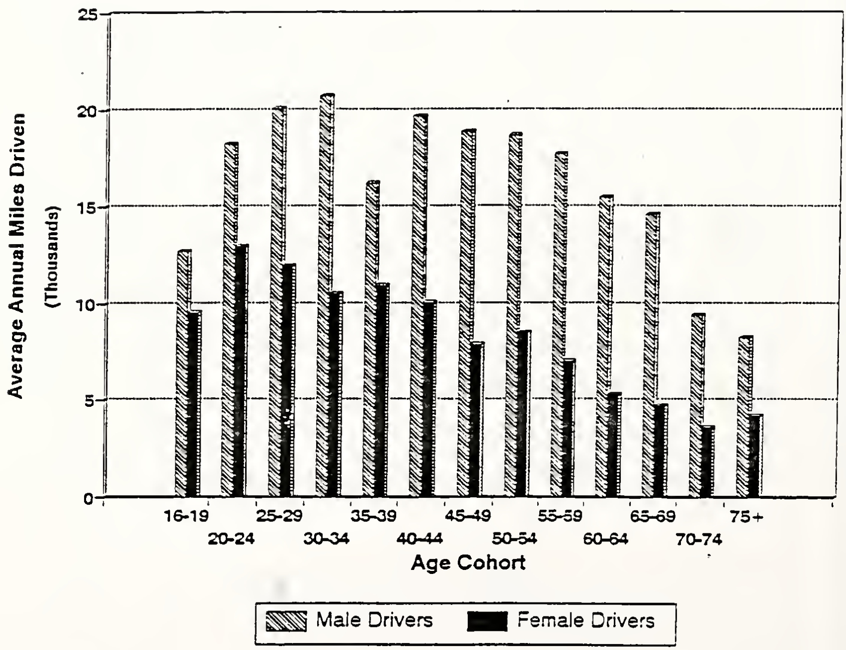

Figure 5.1 Average annual miles driven by male and female Indiana licensed drivers based on 1990 NPTS.

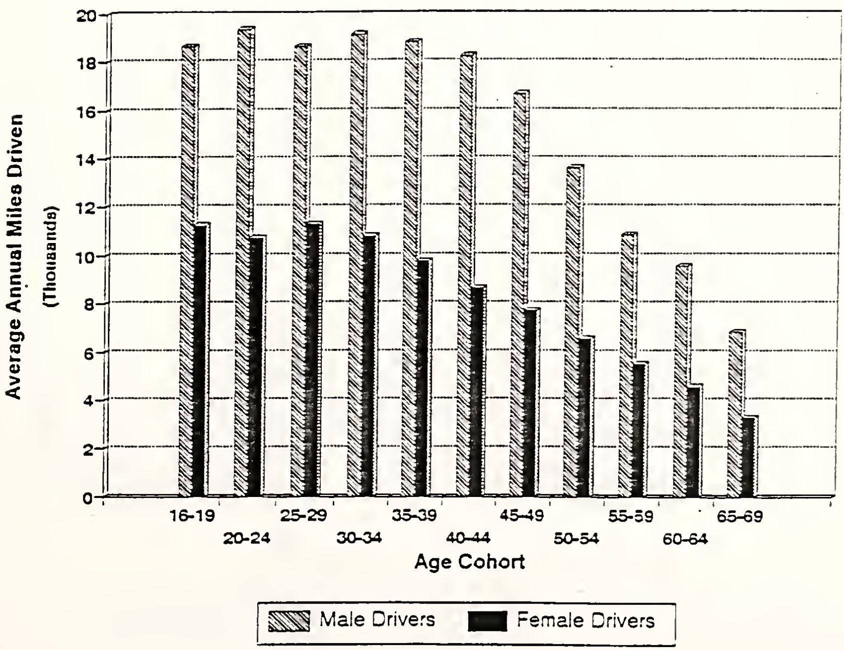

Figure 5.2 Average annual miles driven by male and female licensed drivers in the nation based on 1990 NPTS.

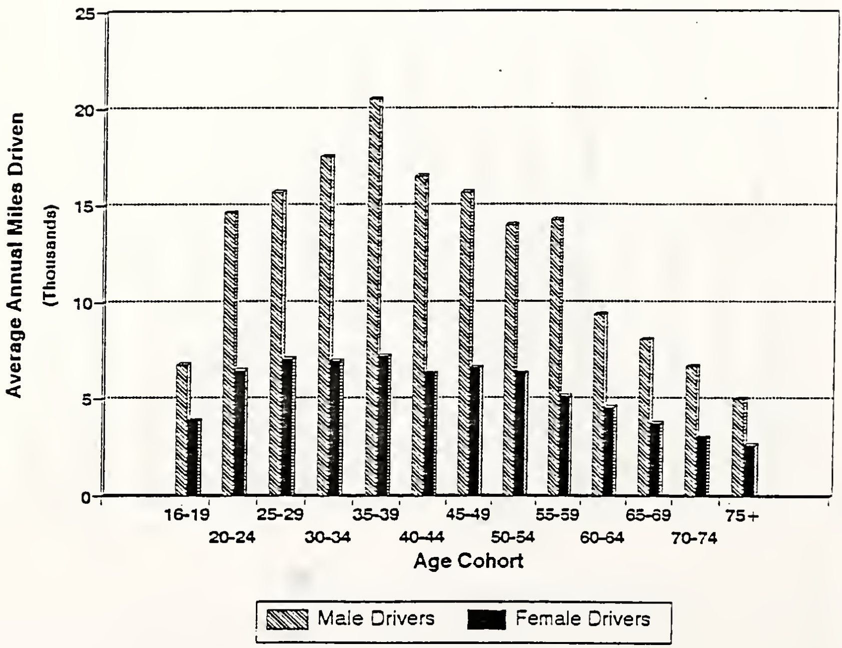

Figure 5.3 Average annual miles driven by male and female licensed drivers in the nation based on 1977 NPTS.

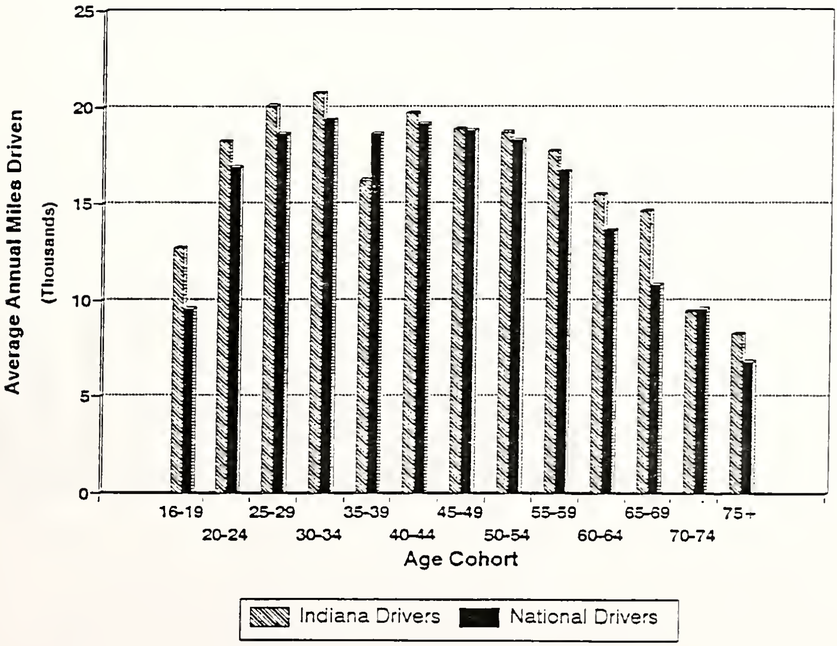

Figure 5.4 Average annual miles driven by male licensed drivers in Indiana and the nation based on 1990 NPTS.

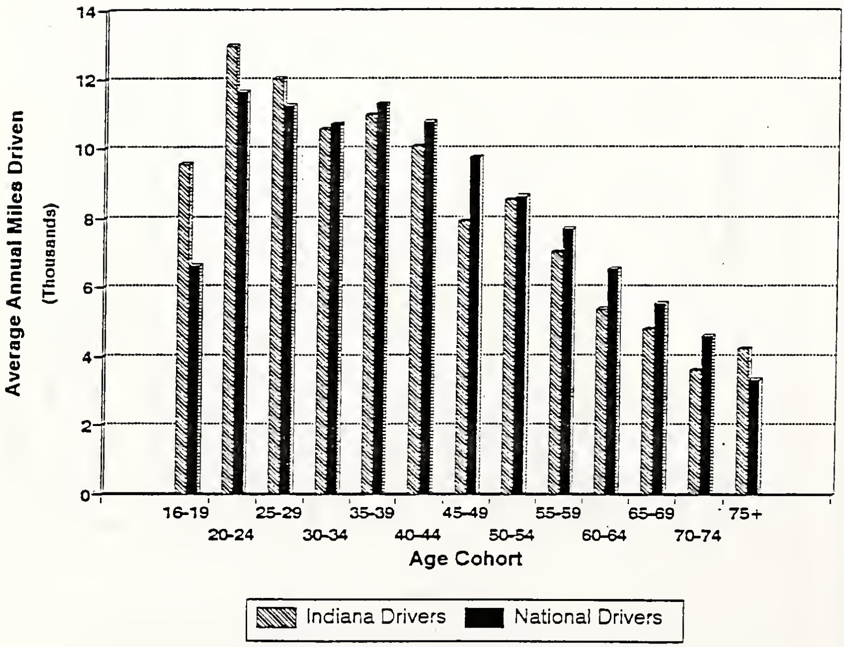

Figure 5.5 Average annual miles driven by female licensed drivers in Indiana and the nation based on 1990 NPTS.

5.2.1 Statistical Comparative Tests of Average Annual Miles Driven

The tests carried out in this section are intended to confirm the graphical inferences drawn in Section 5.2 about the similarities and differences in annual miles driven with respect to sex and age using statistical principles. The statistical similarities or differences in the average annual miles driven by males and females in Indiana obtained from the 1990 NPTS data will determine the final structure of the model. For example, if the average annual miles driven by Indiana males and females is found not to be significantly different statistically, then the age group average -- combined average of male and female licensed drivers -- of annual miles driven will be used in the base model. On the other hand, if the average annual miles driven by Indiana males and females is found not to be significantly different statistically, then the age group average -- the combined average of male and female licensed drivers -- will be used separately in the models. On the other hand, if the average annual miles driven by Indiana males and females is found to be significantly different, then the average annual miles for male and female licensed drivers will be used separately in the model. This effort is aimed at designing efficient statewide VMT fore- casting models to rely on minimum data, based on statistical inferences drawn in the analyses.

In parametric statistical testing procedures, assumptions are made about the distribution of the underlying population -- for example, a normal distribution -- or on large sample sizes and the central limit theorem [27]. This permits the statistical comparative testing of specified characteristics of the population being studied, relying on the properties of the distribution to make inferences about the desired characteristics of the underlying populations. Note in Tables 4.9 through 4.14 that the standard deviations of the average annual miles driven by licensed drivers for both the nation and Indiana, irrespective of sex or age group were in most cases either close to or greater than the group average annual miles driven. This is because there were some "extreme" values of annual miles driven such as 200,000 annual miles in some cases reported in the NPTS data. A review of the NPTS files used in this study showed thatHxhe extreme values are mostly reported by drivers of commercial vehicles. At this point it is important to state that the average annual miles driven per licensed driver obtained in this study includes miles driven by commercial licensed drivers.

With the standard deviations of the average annual miles driven close to or greater than the average annual miles driven -- see Tables 4.9 through 4.14 -- and the lower bound of the average miles driven expected to be positive and not negative, no known distribution is identified to best describe the population distribution of the annual miles driven by licensed drivers with respect to the thirteen age groups.

Hence no assumptions can be made about the distribution of the annual miles driven by licensed drivers in an age group to permit statistical comparative testing using parametric methods. Consequently, this study used a nonparametric testing procedure to statistically compare the annual miles driven as desired. Nonparametric comparative or-distribution-free testing is considered appropriate for use in this study because, it requires minimal assumptions about the distributions of the population being tested. Nonparametric comparative testing procedure is discussed in the following section.

5.2.2 Nonparametric Comparative Testing

Nonparametric or distribution-free comparative testing procedures require minimal assumptions about the population being tested, and are used for both small and large samples. The procedures employ simple statistics based on ranked or ordered sample data. The procedures are simple to implement and are derived from elementary probability considerations. Nonparametric testing procedures are discussed in most applied statistics texts. Nonparametric testing procedures used in this study for statistical comparative testing of the annual miles driven by licensed drivers are adopted from the text, Applied Statistics [27]. The text covers various nonparametric testing procedures for various populations including the procedures comparative studies involving matched sample population studies which has been used in this study.

Comparative studies for matched samples involve the pairing of sample observations X_i and Y_i, from two populations. For example, in this study the annual miles driven by male and female licensed drivers are paired on the basis of the thirteen age groups defined for the model. Nonparametric comparative testing procedures place emphasis on the median η_D of the population of differences of the matched pairs, $D_i=Y_i-X_i$. The four types of matched samples evaluated in this study are as follows:

1. Average annual miles driven by male licensed drivers versus the average annual miles driven by female licensed drivers for Indiana using data in Tables 4.9 and Table 4.10, based on data from 1990 NPTS public use files.

2. Average annual miles driven by male licensed drivers versus the annual miles driven by female licensed drivers for the nation using data in Table 4.11 and Table 4.12 respectively, based on data from 1990 NPTS public files. The same comparative studies mentioned here are carried out for the 1977 NPTS sample using data in Table 4.13 and Table 4.14.

3. Average annual miles driven by male licensed drivers in Indiana versus the annual miles driven by male licensed drivers in the nation, using data in Table 4.9 and Table 4.11, respectively, based on data from 1990 NPTS files.

4. Average annual miles driven by female licensed drivers

in Indiana versus the annual miles driven by female licensed drivers in the nation using data in Table 4.10 and Table 4.12 respectively, based on data from 1990 NPTS files.

The basic concepts supporting the nonparametric testing procedures used in this study are as follows [27]:

1. When the Y_i values tend to be larger than the X_i values, the differences, $D_i=Y_i-X_i$ of the matched pairs tend to be positive and n_D is positive.

2. When the Y_i values tend to be smaller than the X_i values, the D_i values tend to be negative and n_D is negative.

3. When the X_i and Y_i distribution of the matched samples do not differ systematically as in cases 1 and 2, the D_i values typically tend to be positive and negative with approximately equal frequency and the n_D then is near zero.

The median of the population of differences of the matched pairs n_D is thought of as a parameter that measures how far apart the Y and X distributions are. For symmetrical distributions, the median differences n_D and μ_D, the mean of the population differences ($\mu_D=\mu_1-\mu_2$) are equal [27]. The inference for the matched sample is based on the inference procedures for single populations, the population being that of D_i. To test the median difference n_D for matched samples in this study, the Wilcoxon Signed Rank Test for n_D is used.

5.2.2.1 Wilcoxon Signed Rank Test for η_D

If it is assumed that the population of differences D_i is symmetrical, the Wilcoxon signed rank test may be employed for making inferences about the population median difference η_D [27]. In practice in general, the population of differences between matched pairs frequently will be symmetrical, or approximately so [27]. In this study the distribution of the population of differences are assumed to be symmetrical.

5.2.2.2 Assumptions for the Wilcoxon Signed Rank Test for η_D

The assumptions supporting the Wilcoxon Signed Rank test for η_D are as follows [27]:

1. The population of differences D_i is continuous and symmetrical.
2. The differences are a random sample from the population of differences.

The above assumptions are considered valid for this study, because the NPTS household samples are selected based on various random sampling process described in detail in the Public Tape User's Manuals [15, 16, 17]. The household persons including licensed drivers in the randomly selected households in the NPTS are randomly selected. The annual miles reported by licensed drivers interviewed in the NPTS are considered to be random and continuous, because licensed drivers have varied trip making behavior and will make trips of varied lengths depending on various factors such as income, and geographical location -- urban or rural. Thus the annual miles driven by licensed drivers is expected to vary from one licensed driver to another, with values that are expected to be continuous. If the annual miles driven by males and females is continuous and random, then the difference of miles driven for any matched pairs is expected to be random continuous also.

5.2.2.3 <u>Test Alternatives Test</u>

The Wilcoxon signed rank test can be employed for both two-sided and one-sided alternatives concerning n_D. The two types of test alternatives to be considered in this study are presented below:

The two-sided test is used in this study to test whether the average miles driven by matched samples are the same. For example, it is desired to test whether the average miles driven by Indiana male licensed drivers and male licensed drivers nationwide are the same.

The set up of the test is:

$$H_0: n_D=0$$

and

$$H_1: n_D \neq 0$$

The α risk here is the risk of concluding that there is a difference in average annual miles driven by matched samples when, there is no difference.

The one-sided test is used in this study to test whether the average miles driven by matched samples are not equal, such that $D_i>0$. For example, are the average miles driven by male licensed drivers greater than the average miles driven by female licensed drivers?

The set up of the test is:

$$H_0: \eta_D \geq 0$$

and $$H_1: \eta_D < 0$$

The α risk here is the risk of concluding that the difference in average annual miles driven by matched samples is less than or equal th zero when, in fact, they are greater than zero. For example, it is inferred from the plots in Figure 5.1 that the average annual miles driven by male licensed drivers is greater than that of female licensed drivers.

5.2.2.4 Test Statistic

The test statistic for the Wilcoxon test is simple determine, the calculations are presented in the following steps:

1. The absolute difference $|D_i|$ are calculated and ranked R_i.

2. To each rank R_i is attached a plus or a minus sign according to the sign of D_i. For example, if D_i is negative then a negative sign is attached to the rank $(-R_i)$.

3. The signed ranks R_i are then summed and the sum denoted by T.

If a difference D_i should be zero, it is discarded and the sample size reduced accordingly. A typical calculation and results for the calculation procedure described above in Steps 1 through 3 are presented in Section 5.2.2 and Table 5.1.

5.2.2.5 Standardized Test Statistic

Tests concerning n_D based on the Wilcoxon signed rank method when the number of differences is sufficiently large, are based on the standardized test statistic.
The test statistic is presented as follows [27]:

$$z^* = (T - E[T])/\sigma[T] \quad \ldots\ldots\ldots\ldots (5.1)$$

Where

z^* is the standardized test statistic.

$E[T]$ is given by equation 5.2.

$\sigma[T]$ is given by equation 5.3.

α risk is controlled at $n_D=0$.

When $n_D=0$, z^* follows approximately a standard normal distribution.

As a working rule, the normal approximation is considered adequate when n -- the number of matched pairs -- is 10 or more [27]. For this study n=13 -- the number of age groups.

To control the α risk at a specified level when $n_D=0$, the sampling distribution of T when $n_D=0$ needs to be estimated. For $n_D=0$, the sampling distribution has mean and variance stated mathematically in equations 5.2 and 5.3 respectively [27]:

$$E[T]=0 \text{ ....(5.2)}$$

$$\sigma^2[T]=n(n+1)(2*n+1)/6 \text{ ....(5.3)}$$

The sampling distribution of T can be determined exactly for all sample sizes, it depends only on the number of differences.

5.2.2.6 Decision Rules

Decision rules for the Wilcoxon signed rank tests employed for the two types of test alternatives considered in this study (Section 5.2.2.3) are presented below.

The decision rule for the two-sided test for the mean of population of differences can be summarized as follows [27]: When the alternatives are:

H_0: $n_D=0$

and H_1: $n_D\neq 0$

The appropriate decision rule to control α risk at $n_D=0$:

If $|z^*|\leq z(1-\alpha/2)$, accept H_0.

If $|z^*|>z(1-\alpha/2)$, reject H_0.

z^* is given by equation 5.1, and $z(1-\alpha/2)$ may be obtained from statistical tables of cumulative probabilities of the standard normal distribution which is available in any standard statistics text.

The decision rule for the one-sided lower tail test for the mean of population of differences can be summarized as follows [27]:

When the alternatives,

$$H_0: \eta_D \geq 0$$

and $$H_1: \eta_D < 0$$

The appropriate decision rule to control α risk at $\eta_D=0$ is:

If $z^* \geq z(1-\alpha)$, accept H_0.

If $z^* < z(1-\alpha)$, reject H_0.

Again z^* is given by equation 5.1, and $z(1-\alpha)$ may be obtained from statistical tables of cumulative probabilities of the standard normal distribution, which is available in any statistics text.

5.2.3 Statistical Comparative Testing of the Average Annual Miles Driven by Licensed Drivers in Indiana based on 1990 NPTS.

The average annual miles driven by Indiana licensed drivers -- comprising of males and females -- are presented in Table 5.1. The difference D_i of annual miles driven is obtained by subtracting the annual miles driven by female licensed drivers (X_i), from the annual miles driven by male licensed drivers (Y_i). All the differences D_i obtained are noted to be positive.

Table 5.1 Results of statistical comparison test on the average miles driven by Indiana male and female licensed drivers based on 1990 NPTS sample.

Age group	Mean annual miles driven		Absolute Difference	Rank	Signed Rank
(i)	male (Y_i)	female (X_i)	$\lvert D_i = Y_i - X_i \rvert$		
16-19	12,733	9,580	3,153	1	1
20-24	18,236	12,986	5,250	4	4
25-29	20,082	12,026	8,056	6	6
30-34	20,754	10,574	10,180	11	11
35-39	16,236	11,002	5,234	3	3
40-44	19,712	10,100	9,612	7	7
45-49	18,916	7,928	10,988	13	13
50-54	18,685	8,549	10,137	9	9
55-59	17,729	7,057	10,672	12	12
60-64	15,522	5,366	10,156	10	10
65-69	14,656	4,783	9,873	8	8
70-74	9,500	3,614	5,886	5	5
75 and over	8,286	4,237	4,049	2	2
					T=91

Wilcoxon Signed Rank Nonparametric Comparative Test for $n_D \geq 0$

	Test Alternatives	Decision rules	Conclusion
$E[T]=0$			
$\sigma^2[T]=819$	H_0: $n_D \geq 0$	If $z^* \geq 1.645$, accept H_0	Accept H_0 since $z^*=3.18>1.645$. Thus $n_D \geq 0$.
T=91	and H_1: $n_D<0$	If $z^*<1.645$, reject H_0	
$z^*=3.18$	Control α risk at 0.05	But $z^*=3.18$	

It is desired to test whether for a 95 percent confidence level, the average annual miles driven by the male is greater than that of female licensed drivers. Having obtained the value of T from Table 5.1, the following parameters are calculated for n_D=0, using equations 5.1, 5.2, and 5.3:

$\sigma^2[T]$ = 819 (equation 5.2).

T = 91 (from Table 5.1).

z^* = 3.18 (equation 5.1).

E[T] = 0.

α risk is controlled at 0.05 for n_D=0 and $z(1-\alpha) = z(0.95) = 1.645$.

The setup of test alternatives, decision rules and conclusions are presented in Table 5.1. From the results presented in Table 5.1, H_0 is accepted because from the decision rule setup in the table, z^* is greater than 1.645. This means that the population difference n_D is greater than zero and hence that Y_i -- the average annual miles driven by males -- tends to be greater than X_i -- the average annual miles driven by females.

It is inferred from the results in Table 5.1 that, with 95 percent confidence level, the average annual miles driven by male licensed drivers in Indiana is greater than the average annual miles driven by female licensed drivers in Indiana based on the 1990 NPTS data.

5.2.4 Statistical Comparative Testing of the Average Annual Miles Driven by Licensed Drivers in the Nation based 1990 NPTS.

The average annual miles driven by licensed drivers -- males and females -- in the nation are presented in Table 5.2. The difference D_i of annual miles driven is obtained by subtracting the annual miles driven by female licensed drivers (X_i) from the annual miles driven by male licensed drivers (Y_i). All the differences D_i obtained are noted to be positive. It is desired to test whether, for a 95 percent confidence level, the average annual miles driven by male drivers is greater than that of female drivers. Having obtained the value of T from Table 5.2, the following parameters are calculated for n_D=0, using equations 5.1, 5.2, and 5.3:

$\sigma^2[T]$ = 819 (equation 5.2).

T = 91 (from Table 5.1).

z^* = 3.18 (equation 5.1).

E[T] = 0.

α risk is controlled at 0.05 for n_D=0.

$z(1-\alpha) = z(0.95) = 1.645$

The set up of test alternatives, decision rules and conclusions are presented in Table 5.2. From the results presented in Table 5.2, H_0 is accepted because from the decision rule set up in the table, z^* is greater than 1.645. This means that the population difference n_D is greater than zero and hence that Y_i -- the average annual miles driven by male drivers.

Table 5.2 Results of statistical comparison test on the average annual miles driven by male and female licensed drivers in the nation based on 1990 NPTS sample.

Age group	Mean annual miles driven		Absolute Difference	Rank	Signed Rank
(i)	male (Y_i)	female (X_i)	$\|D_i=Y_i-X_i\|$		
16-19	9,612	6,633	2,979	1	1
20-24	16,874	11,648	5,226	4	4
25-29	18,659	11,247	7,412	8	8
30-34	19,374	10,730	8,644	10	10
35-39	18,668	11,312	7,356	7	7
40-44	19,171	10,783	8,388	9	9
45-49	18,812	9,793	9,019	12	12
50-54	18,262	8,644	9,618	13	13
55-59	16,696	7,705	8,991	11	11
60-64	13,658	6,550	7,108	6	6
65-69	10,853	5,551	5,303	5	5
70-74	9,576	4,603	4,973	3	3
75 and over	6,869	3,316	3,553	2	2
					T=91

Wilcoxon Signed Rank Nonparametric Comparative Test for $n_D \geq 0$

	Test Alternatives	Decision rules	Conclusion
$E[T]=0$			
$\sigma^2[T]=819$	H_0: $n_D \geq 0$	If $z^* \geq 1.645$, accept H_0	Accept H_0 since $z^*=3.18>1.645$. Thus $n_D \geq 0$.
$T=91$	and H_1: $n_D<0$	If $z^*<1.645$, reject H_0	
$z^*=3.18$	Control α risk at 0.05	But $z^*=3.18$	

-- tends to be greater than X_i -- the average annual miles driven by females. It may therefore be concluded from the results in Table 5.2 that, with 95 percent confidence, the average annual miles driven by male licensed drivers in the nation tend to be greater than the average annual miles driven by female licensed drivers in the nation based on the 1990 NPTS data.

5.2.5 Statistical Comparative Testing of the Average Annual Miles Driven by Licensed Drivers in the Nation based on 1977 NPTS.

The average annual miles driven by licensed drivers-- males and females -- in the nation are presented in Table 5.3. The difference D_i of annual miles driven is obtained by subtracting the annual miles driven by female licensed drivers (X_i) from the annual miles driven by male licensed drive (Y_i). All the differences D_i obtained are noted to be positive. It is desired to test whether for a 95 percent confidence level, the average annual miles driven by male licensed drivers is greater than that of female licensed drivers.

Having obtained the value of T from Table 5.3, the following parameters are calculated for n_D=0, using equations 5.1, 5.2, and 5.3:

$\sigma^2[T]$ = 819 (equation 5.2).

T = 91 (from Table 5.1).

z^* = 3.18 (equation 5.1).

E[T] =0.

α risk is controlled at 0.05 for n_D=0.

Table 5.3 Results of statistical comparison test of the average annual miles driven by male and female licensed drivers in the nation based on 1977 NPTS sample.

Age group	Mean annual miles driven		Absolute Difference	Rank	Signed Rank
(i)	male (Y_i)	female (X_i)	$\lvert D_i=Y_i-X_i\rvert$		
16-19	6,800	3,947	2,853	2	2
20-24	14,612	6,498	8,114	7	7
25-29	15,697	7,142	8,555	8	8
30-34	17,567	7,031	10,536	12	12
35-39	20,536	7,279	13,257	13	13
40-44	16,540	6,348	10,192	11	11
45-49	15,718	6,683	9,035	9	9
50-54	14,008	6,360	7,648	6	6
55-59	14,290	5,168	9,122	10	10
60-64	9,433	4,619	4,814	5	5
65-69	8,160	3,788	4,372	4	4
70-74	6,773	3,060	3,713	3	3
75 and over	5,063	2,653	2,410	1	1
					T=91

Wilcoxon Signed Rank Nonparametric Comparative Test for $n_D \geq 0$

$E[T]=0$	Test Alternatives	Decision rules	Conclusion
$\sigma^2[T]=819$	H_0: $n_D \geq 0$	If $z^* \geq 1.645$, accept H_0	Accept H_0 since $z^*=3.18>1.645$. Thus $n_D \geq 0$.
T=91	and H_1: $n_D<0$	If $z^*<1.645$, reject H_0	
$z^*=3.18$	Control α risk at 0.05	But $z^*=3.18$	

$z(1-\alpha)=z(0.95)=1.282$.

The setup of test alternatives, decision rules and conclusions are presented in Table 5.3. From the results presented in Table 5.3, H_0 is accepted because, from the decision rule set up in the table, z^* is greater than 1.645. This means that the population difference n_D is greater than zero at 95 percent confidence and hence that Y_i -- the average annual miles driven by males drivers -- tends to be greater than X_i -- the average annual miles driven by female licensed drivers.

It is inferred from the results in Table 5.3 that, with 95 percent confidence the average annual miles driven by male licensed drivers in the nation is greater than the average annual miles driven by female licensed drivers in Indiana based on 1977 NPTS data.

5.2.6 Statistical Comparative Testing of the Average Annual Miles Driven by Male Licensed Drivers in Indiana and the Nation based on 1990 NPTS.

The average annual miles driven by male licensed drivers in Indiana and the nation are presented in Table 5.4. The difference D_i of annual miles driven is obtained by subtracting the annual miles driven by male licensed drivers in the nation (X_i) from the annual miles driven by male licensed drivers in Indiana (Y_i). All the differences D_i obtained are noted to be positive except for the 35-39 and 70-74 age groups, and thus negative signs are attached to the corresponding ranks of the 35-39 and 70-74 age groups as in

Table 5.4 Results of statistical comparison test on the average annual miles driven by male licensed drivers in Indiana and in the nation based on 1990 NPTS sample.

Age group (i)	Average annual miles driven by male drivers: Indiana (Y_i)	Nation (X_i)	Absolute Difference $\lvert D_i=Y_i-X_i \rvert$	Rank	Signed Rank
16-19	12,733	9,612	3,121	12	12
20-24	18,236	16,874	1,362	6	6
25-29	20,082	18,659	1,423	9	9
30-34	20,754	19,374	1,380	7	7
35-39	16,236	18,668	2,432	11	-11
40-44	19,712	19,171	541	4	4
45-49	18,916	18,812	104	2	2
50-54	18,685	18,262	423	3	3
55-59	17,729	16,696	1,033	5	5
60-64	15,522	13,658	1,864	10	10
65-69	14,656	10,853	3,803	13	13
70-74	9,500	9,576	76	1	1
75 and over	8,286	6,869	1,417	8	8
					T=67

Wilcoxon Signed Rank Nonparametric Comparative Test for $\eta_D=0$

	Test Alternatives	Decision rules	Conclusion
$E[T]=0$			
$\sigma^2[T]=819$	H_0: $\eta_D=0$	If $\lvert z^*\rvert \le 1.96$, accept H_0	Reject H_0 since $\lvert z^*\rvert=2.34>1.96$. Thus $\eta_D \ne 0$.
$T=67$	and H_1: $\eta_D \ne 0$	If $\lvert z^*\rvert > 1.96$, reject H_0	
$z^*=2.34$	Control α risk at 0.05	But $z^*=2.34$	

Table 5.4. It is desired to test whether for a 95 percent confidence level, the average annual miles driven by male licensed drivers in Indiana and in the nation are the same. Having obtained the value of T from Table 5.4, the following parameters are calculated for n_D=0, using equations 5.1, 5.2, and 5.3:

$\sigma^2[T]$ = 819 (equation 5.2).

T = 67 (from Table 5.1).

z^* = 2.34 (equation 5.1).

E[T] =0.

α risk is controlled at 0.05 for n_D=0.

$z(1-\alpha/2)=z(0.975)=1.96$.

The set up of test alternatives, decision rules and-con-clusions are presented in Table 5.4. From the results pre-sented in Table 5.4, H_0 is rejected because from the decision rule set up in the table $|z^*|$ is greater than 1.96. This thus means that at a 95 percent confidence level, the population difference n_D is not equal to zero and hence that Y_i -- the average annual miles driven by male licensed drivers -- tends to be greater than X_i -- the average annual miles driven by male licensed drivers in the nation.

It is inferred from the results in Table 5.4 that with 95 percent confidence level that the average annual miles driven by male licensed drivers in Indiana are not equal to the average annual miles driven by male licensed drivers in the nation based on the 1990 NPTS data.

5.2.7 Statistical Comparative Testing of the Average Annual Miles Driven by Female Licensed Drivers in Indiana and the Nation based on 1990 NPTS.

The average annual miles driven by female licensed drivers in Indiana and the nation are presented in Table 5.5. The difference D_i of annual miles driven is obtained by subtracting the annual miles driven by female licensed drivers in the nation (X_i) from the annual miles driven by female licensed drivers in Indiana (Y_i). All the differences D_i obtained are negative except for the following age groups, 16-19, 20-24, 25-29, and 75+, thus negative signs are attached to the corresponding ranks of all age groups except the above listed age groups. The signed ranks are in Table 5.5.

It is desired to test whether for a 95 percent confidence level, the average annual miles driven by the female licensed drivers in Indiana and the nation are the same. Having obtained the value of T from Table 5.5, the following parameters are calculated for n_D=0, using equations 5.1, 5.2, and 5.3:

$\sigma^2[T]$ = 819 (equation 5.2).

T = 67 (from Table 5.1).

z^* = -0.454 (equation 5.1).

E[T] =0.

α risk is controlled at 0.05 for n_D=0.

$z(1-\alpha/2)=z(0.975)=1.96$.

The set up of test alternatives, decision rules and conclusions are presented in Table 5.5. From the results presented in Table 5.5, H_0 is accepted because from the decision rule setup in the Table, $|z^*|$ is less than 1.96. This thus means that at a 95 percent confidence level the population difference n_D is equal to zero and hence Y_i -- the average annual miles driven by male licensed drivers -- tends to be equal to X_i -- the average annual miles driven by male licensed drivers in the nation.

It is inferred from the results in Table 5.5 that, with a 95 percent confidence level the average annual miles driven by male licensed drivers in Indiana is equal to the average annual miles driven by male licensed drivers in the nation based on 1990 NPTS data.

5.2.8 Summary of the inferences Drawn from the Statistical Comparative Tests on Average Annual Miles Driven by Licensed Drivers

From the statistical nonparametric comparative tests carried out in Sections 5.2.2 thrHxgh 5.2.7 the following inferences are drawn:

1. With 95 percent confidence it is inferred that the average annual miles driven by male licensed drivers are greater than the average annual miles driven by female licensed drivers in Indiana based on 1990 NPTS data. Based on this inference, the average annual miles driven by males and females in Indiana based on 1990 NPTS will be used separately in the VMT forecasting models.
2. With a 95 percent confidence level, it is inferred that the average annual miles driven by male licensed drivers are greater than the average annual miles driven

Table 5.5 Results of the statistical comparison test on the average annual miles driven by female licensed drivers in Indiana and in the nation based on 1990 NPTS sample.

Age group (i)	Average annual miles driven by female drivers: Indiana (Y_i)	Nation (X_i)	Absolute Difference $\lvert D_i = Y_i - X_i \rvert$	Rank	Signed Rank
16-19	9,580	6,633	2,947	13	13
20-24	12,986	11,648	1,338	11	11
25-29	12,026	11,247	779	7	7
30-34	10,574	10,730	157	2	-2
35-39	11,002	11,312	310	3	-3
40-44	10,100	10,783	682	5	-5
45-49	7,928	9,793	1,864	12	-12
50-54	8,549	8,644	96	1	-1
55-59	7,057	7,705	648	4	-4
60-64	5,366	6,550	1,183	10	-10
65-69	4,783	5,551	767	6	-6
70-74	3,614	4,603	989	9	-9
75 and over	4,237	3,316	921	8	8
					T= -13

Wilcoxon Signed Rank Nonparametric Comparative Test for $\eta_D=0$

	Test Alternatives	Decision rules	Conclusion
$E[T]=0$			
$\sigma^2[T]=819$	H_0: $\eta_D=0$	If $\lvert z^*\rvert \le 1.96$, accept H_0	Accept H_0 since $\lvert z^*\rvert = -.454 \le 1.96$. Thus $\eta_D=0$.
$T= -13$	and H_1: $\eta_D \ne 0$	If $\lvert z^*\rvert > 1.96$, reject H_0	
$z^*=-0.454$	Control α risk at 0.05	But $z^*= -0.454$	

female licensed drivers nationwide based on 1977 and 1990 NPTS samples.

3. With a 95 percent confidence level it is inferred that the average annual miles driven by male licensed drivers in the nation and the average annual miles driven by male licensed drivers in Indiana are significantly different based on 1990 NPTS. Based on this inference, national data on annual miles driven per male licensed driver should not be used in the statewide long-term VMT forecasting model intended for Indiana in this study, i accurate forecasts are expected from the long-term model.

4. With a 95 percent confidence level, it is inferred that the average annual miles driven by female licensed drivers in Indiana are equal statistically to the average annual miles driven by female licensed drivers in the nation based on 1990 NPTS data. Based on this inference, national data on annual miles driven per female licensed driver may be used in the statewide long-term VMT forecasting model intended for Indiana in this study.

Even though statistical inference 4 discussed above allows for transfer of information on annual miles driven from the national level to the state -- Indiana -- level, the intended statewide VMT forecasting model is abandoned at this stage. The reason here is, inference 3 does not allow transfer of information on average annual miles driven from the state level -- Indiana -- level, because the average annual miles driven by male licensed drivers in Indiana and the nation are statistically different.

The NPTS scheduled for 1995 [35], is expected to contain data on Indiana which could be used in the estimation of growth rates for use in extrapolating annual miles driven into the future. The growth rates yo be based on the scheduled 1995 NPTS which will be based on data specific to Indiana, may be used to develop a long-term statewide VMT model for Indiana.

5.3 Estimation of Licensed Drivers Distribution Factors

The role of the distribution factors estimated in this section is to distribute the total number of licensed drivers for each sex into the thirteen age groups. The data used for the computations of the distribution factors are obtained from FHWA's Highway Statistics for 1990 [12] and 1991 [11]. Highway Statistics [11,12], which is published annually, is selected for data to estimate the distribution factors. The reason for these selections is that "actual" published distribution of licensed drivers Highway Statistics can be compared with forecasted distributions obtained from the short-term statewide VMT model developed in this study. This will enable the tracking and evaluation of the performance and forecasting capabilities of the short-term VMT model. By annually tracking the forecasts of the distribution of licensed drivers, any significant deviation from the published numbers will point out the need for calibration of the model and re-forecasting of the VMT based on the calibrated model.

Computation of the distribution factors used in the construction of the short-term VMT model in this study is carried out using published distributions for licensed drivers in Highway Statistics for 1990 and 1991 with respect to age group and sex. These two years were selected because they are the most recent such data published at the time of this study, starting with 1990 which corresponds to the year the NPTS was carried out. These numbers are reproduced in Tables 4.2 and 4.3 respectively. The distribution factors are estimated by finding the percent of licensed drivers in each age group for each sex separately for 1990 and 1991 which is captured mathematically by equation 5.4.

$$DF_{ij}=(NL_{ij}*100)/NL_{ij} \quad ....(5.4)$$

where

D_{ij} is the distribution factor for age group i of sex j.

NL_{ij} is the number of licensed drivers of sex j in age group i.

NL_{j} is the total number of licensed drivers of sex j.

A typical computation of distribution factors is illustrated below using the 1990 data which is reproduced in Table 4.2. It is desired to compute the distribution factor for male licensed drivers in the 16-19 age group. For this example, the sex of the licensed drivers j is male, and the age group is 16-19. From Table 4.2, which contains data for

1990, the corresponding numbers and computation of the distribution factor are presented below:

D_{ij} = ? for male licensed drivers in the 16-19 age group.

NL_{ij} = 103,639 -- in Table 4.2 -- male licensed drivers in the 16-19 age group.

NL_j = 1,850,007, total number of male licensed drivers.

Computations are carried out similarly for all age groups for male and female licensed drivers distribution in Table 4.2 for 1990. The procedure is repeated for the 1991 data reproduced in Table 4.3. The distribution factors obtained from the computations are presented in Table 5.6 and 5.7, respectively, for males and females. The average of the distribution factors for 1990 and 1990 is adopted for use in the model. This is because there is no indication of any consistent trend in the distribution factors shown in Table 5.6 and 5.7, across the two years--1990 and 1991.

Table 5.6 Male licensed drivers distribution factors used in all the models developed in this study [11,12].

Age Group	Distribution Factors		Model Distribution Factors (Average of 1990 and 1991)
	1990 Male Drivers	1991 Male Drivers	
(i)	(%)	(%)	(%)
16-19	5.6	5.2	5.4
20-24	9.7	9.7	9.7
25-29	12.3	11.8	12.1
30-34	12.6	12.6	12.6
35-39	11.2	11.4	11.3
40-44	9.6	9.8	9.7
45-49	7.3	7.6	7.4
50-54	5.9	6.0	6.0
55-59	5.3	5.2	5.2
60-64	5.4	5.2	5.3
65-69	5.0	4.9	5.0
70-74	4.0	4.1	4.0
75+	6.2	6.6	6.4
Total	100	100	

Table 5.7 Female licensed drivers distribution factors used in all the models developed in this study [11, 12].

Age Group	Percent of Total by Year		Model Distribution Factors (Average of 1990 and 1991) for Male Drivers
	1990 Female Drivers	1991 Female Drivers	
(i)	(%)	(%)	(%)
16-19	5.3	4.9	5.1
20-24	9.4	9.4	9.4
25-29	12.2	11.7	11.9
30-34	12.5	12.5	12.5
35-39	11.1	11.3	11.2
40-44	9.8	9.9	9.8
45-49	7.3	7.6	7.5
50-54	6.0	6.1	6.1
55-59	5.3	5.3	5.3
60-64	5.4	5.3	5.3
65-69	5.2	5.1	5.2
70-74	4.2	4.3	4.2
75+	6.2	6.7	6.5
Total	100	100	

5.4 Chapter Summary

This chapter focussed on two major topics: the performance of statistical tests on annual miles per licensed driver with respect to sex and age to help determine the structure of the cross classification models developed in this study, and the estimation of distribution factors incorporated in the short-term VMT model developed in this study for use in forecasting the distribution of licensed drivers and hence VMT. The results of the statistical tests indicate that annual miles per licensed drivers are different for male and female licensed drivers, and hence separate values of annual miles per licensed driver are used in the two statewide VMT models developed in this study. It was intended to adopt national data on annual miles per licensed driver at the national level for development of a long-term VMT forecasting model for Indiana, because NPTS surveys carried out prior to 1990 NPTS did not capture travel data on any state specifically, including Indiana. Results of the statistical tests lead to the abandonment of the idea to develop a long-term VMT model for Indiana using national data, because the results revealed that annual miles per male licensed driver for Indiana will result inaccurate long-term forecasts. A long-term model could be developed in future, using data specific to Indiana from the next NPTS -- scheduled for 1995 [35].

CHAPTER 6

THE SHORT-TERM STATEWIDE VMT FORECASTING MODEL

6.1 Introduction

This chapter covers the detailed description of one of the two disaggregate cross classification short-term statewide VMT forecasting models developed in this study. The model is programmed into a QUATTRO PRO spreadsheet and named SHORTVMT. SHORTVMT consists of six subsidiary spreadsheets. The six spreadsheets play different roles in the model, from the input data sheets (Sheets 1A and 1B) through the functional class VMT forecasting sheet (Sheet 5), the final product of statewide VMT forecast with respect to FHWA functional classes. This chapter describes of the assumptions supporting the model, model calibration, and model validation. The most likely statewide VMT forecasts from 1993 through 1996 for Indiana is also presented in this chapter.

6.2 Model Description

The model designed to forecast short-term statewide VMT is programmed into a spreadsheet named "SHORTVMT" and will hence be referred to by this name. The SHORTVMT spreadsheet contains six separate spreadsheets which can be found in Tables A-1 through A-6 in Appendix A. The location of each spreadsheet in SHORTVMT can be found in the last row of each table in Appendix A. Each sheet performs a unique function leading to the final short-term statewide VMT forecast for Indiana. Sheet 1 (A) and Sheet 1 (B) deal with handling input data. Sheet 5 is where the final product of statewide VMT forecasts with respect to FHWA functional classes are obtained. Information on instant macro commands is available in Sheet 2 for printing the results of all the six sheets including Sheet 2 obtained after each run.

6.2.1 Short-Term VMT Model Assumptions

Along with the assumptions stated in Section 3.4, the following assumptions are related to the short-term VMT model:

1. It is assumed that the average annual miles per licensed driver is constant in the short-term. The period 1990 through 1996 is considered short-term in this study and the reasons for this choosing this period for short-term VMT forecasting are discussed in Section 6.2.3.
2. The licensed drivers distribution factors used in

distributing the total population of licensed drivers for each sex into the respective age groups (see column A and B in Sheet 3 in Table A-3) is assumed constant in the short-term.

6.2.2 Description of the Short-Term VMT Model

The input data required to run the final version of SHORTVMT model are presented below as follow with respect to the sheets in SHORTVMT:

Sheet 1(A) in Table A-1.

1. Population forecast for the state for the year for which VMT forecast is desired.
2. Year of the population forecast.
3. Percent of population 16 years and over -- driving age population.
4. Percent of 16 years and over population who are licensed drivers.
5. Percent of total licensed drivers who are male.

Sheet 1(B) in Table A-1

6. The mileage for functional classes in Group X.

Data items 1 and 3 may be obtained from population forecasts. In this study, the data on population forecasts for Indiana are obtained from Indiana Business Research Center of the Indiana University School of Business [34].
The population data consists of population forecasts with

respect to sex and age from the year 1985 through 2020. Data for items 4 and 5 listed above were obtained from data on driver registrations in Highway Statistics. Input data on licensed drivers were based on trends in driver licensing published in Highway Statistics and on assumptions that most likely describe future population of licensed drivers. The input data in Sheet 1(A) are carried over into Sheet 3 (Table A-3), in which forecasts of licensed drivers population by sex and age category are made. To obtain the distribution of licensed drivers by sex and age category as shown in column C and column D of Sheet 3, the total number oHxlicensed drivers for male and female licensed drivers is first estimated using data from Sheet 1(A). Having obtained the total number of licensed drivers for each sex, the distribution of licensed drivers with respect to sex and the age groups defined for the model are obtained using the respective distribution factors for male and female licensed drivers respectively (see columns A and B of Sheet 3 in Table A-3). The values in the two tables (Tables A-1 and A-3), are used to illustrate the computation process leading to forecasts of licensed drivers by sex and age category. The following parameters in Sheet 1(A) are used to illustrate the computation process in SHORTVMT.

Let

IP = Indiana population forecast =5,585,500.

P16 = Percent of population (pop.) 16 years and over = 77.0%.

P16L = Percent of 16 years and over population who are licensed drivers = 85.0 %

PML = Percent of licensed drivers who are males = 51.0%.

With the above input data in Sheet 1(A), the computations leading to the forecasts of licensed drivers with respect to sex and age groups in Sheet 3 are as follows:

Forecast of population (pop.) 16 years and over = IP*P16/100

= F16 = 5,585,500*77.0/100 = 4,300,835.

Forecast of pop. of licensed drivers = F16*P16L/100

= F16L = 4,300,835*85/100 = 3,655,710.

Forecast of pop. of male licensed drivers = F16L*PML/100

= FML = 3,655,710*51/100 = 1,864,412.

Forecast of pop. of female licensed drivers = FML =

= F16L*(100-PML)/100 = 3,655,710*49/100

= 1,791,298.

The total population of male and female licensed drivers is distributed among the thirteen age groups for each sex using the distribution factors in column A and D of Sheet 3 for male and female licensed drivers respectively. The distribution process is carried out using equation 6.1.

$$NL_{ij} = (DF_{ij} * NL_j)/100 \quad ....(6.1)$$

where

DF_{ij} is the distribution factor for age group i of sex j in Sheet 3 in Table A-3.

NL_{ij} is the forecasted number of licensed drivers of sex j in age group i.

NL_j is the forecasted total number of licensed drivers of sex j.

Presented below is a numerical example to illustrate the computation process. For example, the forecast of the number of male licensed drivers in the 16-19 age group is desired, where j= male and i = 16-19 age group.

Using equation 6.1, the computation is:

DF_{ij} = 5.4%

NL_j = 1,864,412

Knowing DF_{ij} and NL_j, equation 6.1 is used to obtain NL_{ij}:

NL_{ij} = 1,864,412*5.4/100 = 100,678.

The forecast of male licensed drivers in the 16-19 year age group 100,678 as shown in Sheet 3 (Table A-3) for the 16-19 year age group.

The forecasted number of licensed drivers by sex and age categories are copied to Sheet 4 (Table A-4). The total VMT for each sex and age combination is forecasted and then summed up over all the age combinations to obtain the statewide VMT. The statewide forecasting process discussed above is captured by equation 3.1 in Section 3.2. For example, the total VMT estimate of 3,297,872,892 -- in Sheet 4 -- for male licensed drivers in the 20-24 year age group is obtained from the product of the total predicted number of licensed drivers and the annual miles per licensed driver for this age group. The calculations are as follows:

Total VMT for male licensed drivers in the 20-24 age group

= 180,848 * 18,236 annual miles/driver = 3,631,730,888. Values used in these calculations can be found in Sheet 4, the number of male licensed drivers in the 20-24 age group in column A and the annual miles/male driver in the 20-24 age group in column C.

The statewide VMT of 48,338,915,071 in Sheet 4 (column G) is obtained by adding up the total VMT for all 13 age groups.

6.2.3 Short-Term Statewide VMT Forecasts

This section concerns the use of the statewide short-term VMT model to forecast statewide VMT for the period from 1990 through 1996. The period from 1990 through 1996 is considered short-term in this study because within this period no significant change in annual miles driven per licensed driver is expected. Within this period, no significant changes are expected in factors such as transportation modal shares, the state road network, speed limits posted along the links in the state road network, and the economy of the state and nation -- major factors that may cause changes in annual miles per licensed driver. The terminal year of 1996 is selected because the next NPTS is planned for 1995 [35] and data from this survey is expected to be used to update the annual miles per licensed driver estimate VMT models developed in this study. The 1995 NPTS data is assumed will capture any changes in annual miles per licensed driver that may be caused by any changes in the factors mentioned above such as transportation modal shares, the state road network, speed limits posted along the links in the state road network. Another reason for selecting 1996 as the terminal year for the short term analysis is based on the fact in transportation planning, short-term forecasts are usually performed for five year periods [28].

6.2.3.1 Population Forecasts Used for Short-Term VMT Forecasting (1990-1996)

The population forecasts from 1990 through 1996 for the State of Indiana were obtained from the Indiana Business Research Center [34]. The data are presented in Table 6.1, together with the percent of the population sixteen years and over -- driving age population -- for each forecast year. The percent of total state population of driving age was found to be consistently seventy-seven percent (77%) of the total state population forecasts, when rounded off to the nearest whole number. Thus, for all short-term analyses, the percent of state population 16 years and over is considered constant at 77 percent.

6.2.3.2 Estimation of the Percentage of Driving Age Population as Licensed Drivers.

The percentage of licensed drivers within the driving age population -- 16 years and over -- for Indiana from 1980 through 1991 is presented in Table 6.2 to the nearest whole number. The percentages range from 87 in 1980 to 80 in 1991, showing a decreasing trend in the percentage values over the years from 1980 through 1991. The last census was carried out

Table 6.1 Total state population forecasts used in short-term VMT forecasting [34]

Forecast Year	State Population Forecasts	Percent of State Population of Driving Age (%)
1990	5,544,154	76.60
1991	5,585,500	76.60
1992	5,594,610	76.75
1993	5,604,480	76.89
1994	5,615,070	77.04
1995	5,626,440	77.19
1996	5,632,880	77.39

in 1990 which produced a percentage of 85, a decrease of two percent over 10 years. The percentage for 1991 of 80 is considered too great a difference from the 1990 value of 85 percent. Table 6.1 shows the percentage of the State population of driving age to be stabilizing at 77 percent. The 80 percent reported for driving age population as licensed drivers for 1991 seems to be incorrect. From the trends in Table 6.2, which shows the percentages of driving age population registered as licensed drivers, a percentage in the region of 85 seems more likely for 1991, based on linear interpolation. At the preliminary stages of statewide VMT forecasting using the short-term model in this study, linear interpolated values of the percentage of driving age population who are registered as licensed drivers from 85 percent in 1990 to 83.8 in 1996 were used to forecast statewide VMT from 1990 through 1996. Statewide forecasts obtained using the interpolated values were compared with statewide VMT forecasts based on a fixed value of 85 percent, from 1990 through 1996. The fixed value of 85 percent which is based on the most recent Census (1990), is assumed to be the upper bound value of the percentage of driving age population as registered drivers in Indiana for the short term period of analyses in this study. The absolute percent differences in statewide VMT forecasts between using the interpolated percent values of 85 in 1990 to 83.8 in 1996 and a fixed value of 85 percent were noted to be insignificant, with a maximum value of approximately 3 percent for corresponding forecasting years. The statewide VMT forecasts obtained using the fixed value of 85 percent were noted to have slightly higher statewide VMT estimates for each forecasting year. With current concerns about underestimation of VMT in previous years [3], the use of a fixed value of 85 percent to generate an upper bound on statewide VMT forecasts is a step in the right direction to address concerns on underestimation of VMT.

If the decreasing trend in the percentages -- interpolated values -- is to continue into the future, then the fixed percentage of 85 can be considered as an upper bound estimate. The use of the interpolated values from 85 percent in 1990 to 83.8 in 1996, which may not occur in the future, may result in underestimation of statewide VMT forecasts for the respective years. Hence, for all short-term VMT forecasting in this study, a fixed value of 85 percent of state driving age population as registered drivers will be used in the model to generate an upper bound for statewide VMT forecasts.

Table 6.2 The percent of driving age population registered as licensed drivers from 1980 through 1991 [13, 14, 15].

Year	Percent of Driving Age Population--16 years and over--Who are Registered as Licensed Drivers
1980	87 %
1985	86 %
1990	85 %
1991	80 %

6.2.3.3 Estimation of the Percent of Male and Female Licensed Drivers

The percent of male and female licensed drivers for Indiana -- to the nearest whole number -- from 1965 through 1991 is presented in Table 6.3 and Figure 6.1. It will be noted in Table 6.3 and Figure 6.1 that the percent of male licensed drivers shows a decreasing trend from 60 percent in 1965 to 51 percent in 1985. Thereafter, the percent of male licensed drivers has been stable at 51 percent. The percent of female licensed drivers has, on the other hand shown an increasing trend -- from 40 percent in 1965 to 49 percent in 1985. Thereafter, relative to the male licensed drivers, the percent of female licensed drivers has been stable at 49 percent.

Table 6.3 The percent of licensed drivers with respect to sex of total licensed drivers in Indiana from 1965 through 1991 [13, 14, 15].

Year	Percent of Licensed Drivers	
	Male Drivers (%)	Female Drivers (%)
1965	60	40
1970	55	45
1975	53	47
1980	52	48
1985	51	49
1990	51	49
1991	51	49

Based on the trends in Table 6.3 and Figure 6.1, two alternatives were considered in an attempt to predict the distribution of licensed drivers in the future.

For the first alternative (referred to hereafter as Alternative A), the percent values of male and female licensed drivers is assumed to remain constant at 51 and 49 percent respectively for the period of analysis -- 1990 through 1996. This is based on the assumption that the constant trend shown for the period 1985 through 1991 will continue through 1996. Following the trends in Figure 6.1, percent values of 51 percent and 49 percent were adopted for male and female licensed drivers for the year 1992, because the 1992 Highway Statistics is yet to be published. The percent values of 51 percent for males and 49 percent for females are based on the assumption that the constant trend shown for the period 1985

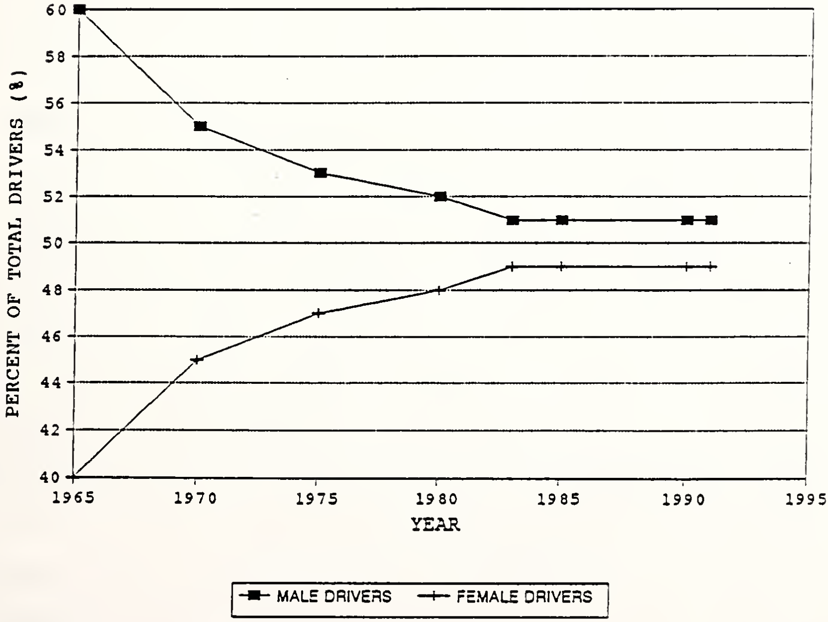

Figure 6.1 Percent of licensed drivers with respect to sex of total licensed drivers in Indiana from 1965 through 1991 [13, 14, 15].

through 1991 will continue through 1992.

For the second alternative (referred to hereafter as Alternative B), the percent values of male and female licensed drivers is assumed to remain constant at 50 percent each for the period of analysis -- 1993 through 1996. The percent of licensed drivers of total number of licensed drivers in the State of Indiana with respect to sex are noted to be 51 and 49 percent for male and female licensed drivers respectively for the years 1990 and 1991 (Highway Statistics). The percentages for 1992 are assumed to be 51 and 49 for male and female licensed drivers (based on past trends as discussed above).

6.2.3.4 Summary of Predictor Variables Selected for the Short-Term VMT Forecasting

A summary of predictor variables for short-term VMT forecasting for the two alternatives being considered are presented in Table 6.4. Note that input data required in Sheet 1(B) for Group X functional class mileage are not required to generate statewide VMT forecasts. The Group X functional class mileage is required in the distribution of statewide VMT forecasts into the respective functional classes in the state road network (Table 1.1).

6.2.3.5 Short-Term Statewide VMT Forecasts for the Two Alternatives

The predictor variables presented in Table 6.4 are used as input data for SHORTVMT. The statewide VMT estimates and forecasts obtained for the two alternatives are presented in

Table 6.5. In SHORTVMT, statewide VMT estimates can be found in the last row of column G in Sheet 4 (Table A-4). The statewide VMT forecasts for 1990 through 1992 are backforecasts of statewide VMT, relative to the year this study was carried out (1993). Statewide VMT estimates for this period are available from INDOT [40] and Highway Statistics [11, 12].

6.2.3.6 The Most Likely Short-Term Statewide VMT Forecasts

The most likely forecasts of statewide VMT of the two alternatives -- Alternative A and Alternative B -- are a matter of judgment as well as technical procedures. In the judgment of the researchers in this study, Alternative A forecasts from 1990 through 1996 and the Alternative B forecast for 1996 are considered the most likely forecasts. The basis for the selection of the most likely forecasts are discussed below. Historical trends in licensed driver registration presented in Figure 6.1 seem to support the choice of Alternative A as producing the most likely forecasts. This is because the state population forecasts presented in Table 6.1 for 1990 through 1996 show the state population stabilizing around 5,600,000 for that period, coupled with the fact that the percent of state population of driving age is forecasted to stabilize around 77 percent and the registration of new licensed drivers within the short-term forecast period is not expected to change significantly relative to the existing distribution of licensed drivers.

The statewide VMT forecasts in Table 6.5 show that, even if the distribution of licensed drivers changed to 50 percent for each sex, the absolute percent difference in statewide VMT is insignificant -- less than 1 percent -- with respect to 51 and 49 percent for male and female licensed drivers for the period from 1993 through 1996.

6.2.3.7 Comparison of FHWA and Model Statewide VMT Estimates

The comparison of statewide VMT estimates obtained from the short-term VMT model with estimates published in FHWA's Highway Statistics from 1990 through 1992 are presented in Table 6.6. The statewide estimates obtained from the model were found to be approximately 12 percent less than the VMT estimates published in Highway Statistics that have been supplied by INDOT to FHWA. The Highway Statistics VMT estimates will also be referred to as either FHWA estimates or INDOT estimates.

The approximately 12 percent difference between the model-generated statewide VMT estimates and FHWA estimates may be attributed to INDOT's inaccurate VMT estimates for some road functional classes such as minor collectors, urban collectors, and local roads that have been neglected in the state road inventory. The neglected road functional classes, thus have inadequate traffic data in the state road inventory which may not be representative of the respective functional classes statewide. The use of these inadequate data may re-

Table 6.4 Summary of predictor variables selected for the short-term VMT forecasts in this study.

Predictor Variable	Alternative A	Alternative B
Indiana Population Forecast	The population forecasts in Table 6.1 are used for each Alternative.	
Analysis Period	1990 - 1996	1993 - 1996
Percent of State Population 16 years and over	77 %	77 %
Percent of 16 years and over Population Registered as Licensed Drivers	85 %	85 %
Percent of Total Licensed Drivers who are Male	51 %	50 %
Percent of Total Licensed Drivers who are Female	49%	50%

Table 6.5 Short-Term Statewide VMT Forecasts

Forecast Year	Alternative A (Annual Miles)	Alternative B (Annual Miles)	Percent Difference (A-B)/A
1990	47,981,091,997**	-	
1991	48,339,915,282**	-	
1992	48,417,756,270**	-	
1993	48,503,174,781**	48,208,648,645	0.61 %
1994	48,594,824,429**	48,299,777,837	0.61 %
1995	48,693,224,477**	48,397,580,442	0.61 %
1996	48,748,958,540**	48,452,976,113**	0.61 %

** The most likely forecasts.

Table 6.6 Comparison of FHWA's statewide VMT estimates with estimates from the Short-Term VMT Model based on selected variables in Table 6.4.

Year	Statewide VMT estimates (Annual Miles)		Percent Difference (A-B)/A (%)
	FHWA (A)**	Model (B)	
1990	53,697,000,000	47,981,091,997	11
1991	54,266,000,000	48,339,915,071	11
1992	55,742,482,515*	48,417,756,270	13

* The 1992 statewide VMT estimate obtained from INDOT [36].
** FHWA estimates obtained from Highway Statistics [11,12].

sult in over estimation of statewide VMT for these neglected functional classes in the state road inventory. The traffic data used in the estimation of VMT on minor collectors, urban collectors is based on traffic data obtained on less than 1 percent of the total state mileage for each functional class (see Table 1.1). The traffic data used in VMT estimation on local roads that are not represented in the state road inventory, are based on very limited traffic data obtained from 5 and 10 minute coverage counts on a few local roads [41,42].

Until adequate traffic data are available to represent all the functional classes in the state network to produce more accurate traffic count-based statewide VMT estimates, the VMT estimates obtained from the short-term VMT model may be considered to be more accurate statewide estimates compared to the current statewide INDOT VMT estimates.

The use of Highway Statistics VMT estimates from the year 1990 and 1991 and INDOT's estimate for 1992 to compare with model-generated statewide VMT estimates is based on the fact that VMT estimation has been given more attention since 1990. The passage of the 1990 Clean Air Act Amendments has prompted the review of FHWA guidelines for VMT estimation -- the HPMS Field Manual [10] -- and EPA's VMT Forecasting and Tracking Guidance [20]. Researchers in this study have critically reviewed INDOT's VMT estimation procedure and found it to conform to relevant guidelines [10, 20], and thus have confidence in the VMT estimates submitted to FHWA by INDOT and published in Highway Statistics from 1990 through 1992. Highway Statistics statewide VMT estimates for 1990 and 1991, and INDOT's statewide VMT estimates for 1992 are used in the calibration and validation of the VMT models developed in this study.

6.2.4 Model Calibration

This section concerns the calibration of the short-term VMT forecasting model to forecast VMT with respect to the twelve road functional classes under FHWA's Functional Classification System. INDOT's statewide traffic count-based VMT estimates are reported for twelve roads functional classes in the state network -- Table 1.1. The non-traffic count-based statewide VMT forecasting model developed in this study is calibrated to generate traffic count-based VMT estimates with respect to all functional classes found in the state network. This is to enable comparison of VMT estimates obtained from the models developed in this study to the estimates obtained using the INDOT method. The final product of the calibration process in SHORTVMT (Sheet 5 in Table A-5) shows a typical set of factors employed in the distribution of statewide VMT obtained from the model into statewide VMT with respect to the functional classes in the state network.

The objective of the calibration process is to obtain a short-term VMT forecasting model to reproduce the historical VMT estimates for the various functional classes used in the calibration process. The ability of the calibrated model to reproduce the historical data used in the calibration process is an indication of the forecasting capability of the calibrated model. To calibrate the model, the twelve road functional classes were placed into two groups, namely Group X and Group Y. Group X represented the group of functional classes with adequate traffic counts and Group Y represented the functional class of roads neglected in the state road inventory. The composition of each group may be found in Sheet 5 in Table A-5. The theory here is, statewide VMT estimates for Group X functional classes reported in Highway Statistics over the past three years are considered accurate. The reason for this consideration is based on the fact that road classes in Group X have had traffic data that are reasonably representative of functional classes in the group statewide in the state road inventory in the period -- 1990, 1991, and 1992 -- used for VMT estimation. VMT for Group Y roads is estimated by subtracting VMT estimates for Group X roads obtained from Highway Statistics from the statewide VMT estimate generated by the short-term VMT forecasting model, SHORTVMT. The percentages of total statewide VMT estimate for Group X roads of the statewide VMT estimate obtained from the short-term VMT forecasting model for three years 1990, 1991 and 1992 are presented in Table 6.7. The percentages in Table 6.7 show the VMT estimates for the Group X roads to be 90.63, 90.52, and 91.66 percent of the statewide VMT estimates from SHORTVMT (in Table 6.5) for the years 1990, 1991 and 1992, respectively. The percentages obtained for the three years -- 1990, 1991, and 1992 -- do not show any trend but are close to each other, within 90 and 92 percent. The average of the percentages for the three years -- 90.94 percent in Table A-5 -- is adopted for the model as the share of the statewide VMT for Group X roads, with the Group Y share being the remaining 9.06 percent.

The total mileage of the state road network open to traffic for the three years (see Table 6.12) was found to be 91,908 miles, 92,029 miles, and 92,019 miles, respectively for the years 1990, 1991 and 1992. The state network mileage open to traffic for the three years show no trend, but are however close to each other and centered on 92,000, miles for the period. It could thus be stated that if the state network mileage does not change significantly in the short-term -- 1990-1996 -- and no there is major reclassification of roads, then the factors of 90.94 percent for Group X roads and 9.06 for Group Y roads for distributing statewide VMT among the two groups are likely to remain the same.

The next step in the calibration was to obtain factors to be used for distributing the Group X total statewide VMT estimates into statewide VMT estimates for each functional class in the group. The first step was to obtain the VMT estimates for each functional class in Group X from Highway Statistics for 1990, 1991 and 1992. This is presented in Table 6.8. The percent contribution of VMT to the Group X total is computed for each functional class for each of the three years and presented in Table 6.9. The percentages in

Table 6.7 FHWA and SHORTVMT statewide VMT estimates and VMT distribution factors for VMT estimation for Group X and Group Y roads used in first calibration of SHORTVMT.

	Year		
	1990	1991	1992
Statewide estimates generated from SHORTVMT (annual miles) A	47,981,091,997	48,339,915,071	48,417,756,270
Group X statewide VMT from FHWA statistics (annual miles) B	43,486,000,000	43,759,000,000	44,382,088,195
Group Y statewide VMT from A and B above (A-B) (annual miles) C	4,495,091,997	4,583,915,071	4,035,668,075
Percentages			
Percent of Group X VMT estimate of model statewide VMT	90.63 %	90.52 %	91.66 %
	average = 90.94 % **		
Percent of Group Y VMT estimate of model statewide VMT	9.37 %	9.48 %	8.34 %
	average = 9.06 % **		

** Distribution factors used in SHORTVMT model--see Table A-5 in Appendix A.

Table 6.9 do not show any trend from 1990 through 1992, but were found to be reasonably close to each other. Hence the average percent contribution of each functional class to the Group X total statewide VMT estimate using for the three years -- 1990, 1991, 1992 -- was computed and used in the model. The assumption here is that the percent contribution to the Group X VMT estimate by each functional class will not change significantly in the short-term if the state network mileage open to traffic for each functional class does not change significantly in the near future. Because the state road-network is not expected to change significantly in the short-term -- 1990 through 1996 -- the average percent contribution by each functional class to the statewide Group X VMT estimate presented in Table 6.9 is incorporated in the short-term VMT.

From the review of INDOT's VMT estimation procedure presented in Section 2.3.3, VMT estimates for functional classes neglected in the state road inventory such as minor collectors, urban collectors, and local roads -- Group Y-functional classes -- were noted to be inaccurate, and more specifically overestimated (see Section 6.2.4.7). Factors for distributing Group Y total VMT into the respective functional classes in the group based on inaccurate VMT estimates for the neglected functional classes will obviously lead to inaccurate Group Y functional class VMT forecasts. No distribution factors were obtained for the functional classes in Group Y, and VMT forecasts for roads in Group Y are reported in the model in Sheet 5 as a combined estimate for the group.

6.2.5 Model Validation

Model validation is an important step in model development. In this study, model validation involved the evaluation of the forecasting capabilities of the calibrated short-term VMT forecasting model. The evaluation process involved the use of the short-term VMT model to estimate VMT for each functional class in Group X for the years 1990 through 1992. The input data for Alternative A (see Table 6.4 and Section 6.2.4.3) are used for estimation of statewide VMT estimates for the various functional classes in Group X. The estimates obtained from the calibrated SHORTVMT model are then compared with the FHWA estimates for the three years presented in Table 6.8.

The percent difference is used as measure of how well the calibrated short-term VMT model reproduces the FHWA estimates in Table 6.8. The percent difference computations were carried out using equation 6.2:

$$PADIFF_j = (FHWAVMT_j - MODELVMT_j) * 100 / FHWAVMT_j \quad \ldots\ldots\ldots\ldots (6.2)$$

where

$PADIFF_j$	is the percent difference between the FHWA statewide VMT estimate and the SHORTVMT statewide VMT estimate for year j.
$FHWAVMT_j$	is FHWA statewide VMT estimate for year j.

Table 6.8 Indiana statewide VMT estimates for functional classes in Group X from <u>Highway Statistics</u> [11, 12, 36]

Functional Class	FHWA Code	Annual Vehicle Miles of Travel		
		1990	1991	1992
Interstates- Rural	01	6,640,000,000	6,943,000,000	6,577,614,995
Interstates- Urban	11	5,279,000,000	5,104,000,000	5,544,637,985
Freeways and Expressways (Principal Arterial) -Urban	12	923,000,000	949,000,000	710,456805
Other Principal Arterial - Rural	02	4,124,000,000	4,132,000,000	5,105,890,100
Other Principal Arterial - Urban	14	6,942,000,000	7,205,000,000	8,077,963,620
Minor Arterial - Rural	06	5,590,000,000	5,617,000,000	3,934,000,660
Minor Arterial - Urban	16	5,239,000,000	5,440,000,000	5,493,689,095
Major Collector - Rural	07	8,749,000,000	8,369,000,000	8,937,834,935
Year Total		43,486,000,000	43,759,000,000	44,382,088,195

$MODELVMT_j$ is the statewide VMT estimate obtained from the short-term VMT model SHORTVMT for year j.

Using the percent difference as a performance measure of the models, a zero percent difference will indicate a perfect prediction of FHWA VMT estimates. The closer the percent difference is to zero the closer the model-generated VMT estimates are to the FHWA estimates. In this study the absolute percent differences will be used in the evaluation the model-generated VMT estimates compared to FHWA estimates. Because the percent difference values may be either positive or negative, the signs of the calculated percent differences will used in the evaluation of the prediction capabilities of the models. For example, if all percent differences are positive, this will indicate that the model is consistently underestimating the FHWA VMT estimates. A reasonable model should generate VMT estimates around the FHWA estimates which will result in negative and positive percent difference values. In the judgement of the researchers in this study, absolute percent differences of 10 percent will be considered acceptable.

Statewide VMT estimates from Highway Statistics and from the short-term VMT model are compared in the model validation process. The first comparison involves the comparison of the total of all statewide VMT estimates for all functional classes in Group X from 1990 through 1992. The percent differences for this comparison are presented in Table 6.10.

In Table 6.10 are presented the comparison of total Group X statewide FHWA VMT estimates with SHORTVMT estimates. The signs of the percent difference values presented in Table 6.10 are noted to be positive and negative. This indicates that the model is neither consistently overestimating nor underestimating the total Group X statewide FHWA VMT estimate. The absolute percent differences are noted to be less than 1 percent for the three years -- 1990, 1991 and 1992. This indicates that the short-term VMT model SHORTVMT is well calibrated to predict total statewide VMT for Group X.

In Table 6.11 are presented the comparison of FHWA's VMT estimates for functional classes in Group X with corresponding estimates obtained from SHORTVMT. The percent differences, together with the VMT estimates used to compute the absolute differences, are presented in the table. The signs of the percent difference values presented in Table 6.11 are noted to be positive and negative. This indicates that the model is neither consistently overestimating nor underestimating the FHWA's VMT estimates for functional classes in Group X. The absolute percent differences for four functional classes -- rural interstates, urban interstates, urban minor arterials, and rural major collectors -- are noted to be less than 5 percent for all the three years (1990, 1991 and 1992). The absolute percent differences for four other functional classes -- urban freeways and expressways, rural and urban other principal arterials, and rural minor arterials -- were found to be greater than 5 percent for some of the three years.

Table 6.10 Comparison of Group X statewide VMT estimates from FHWA with SHORTVMT estimates after first calibration.

Year	Total Statewide VMT Estimates for Group-X (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
1990	43,486,000,000	43,634,005,062	-0.34
1991	43,759,000,000	43,959,409,366	-0.46
1992	44,382,088,195	44,031,107,552	0.79

Table 6.11 Comparison of Group X statewide VMT estimates from FHWA with SHORTVMT estimates for functional classes in Group X after first calibration.

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
Rural Interstates FHWA Code : 01			
1990	6,640,000,000	6,684,170,977	-0.67
1991	6,943,000,000	6,734,018,750	3.01
1992	6,577,614,995	6,745,001,995	-2.54

Table 6.11, Continued

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
Urban Interstates FHWA Code : 11			
1990	5,279,000,000	5,279,189,366	0.00
1991	5,104,000,000	5,318,559,370	-4.20
1992	5,544,637,985	5,327,233,987	3.92
Urban Freeways and Expressways FHWA Code : 12			
1990	923,000,000	859,970,789	7.15
1991	949,000,000	863,361,721	9.02
1992	710,456,805	864,769,872	-21.72
Rural Other Principal Arterial FHWA Code : 02			
1990	4,124,000,000	4,426,020,314	-7.32
1991	4,132,000,000	4,459,027,737	-7.91
1992	5,105,890,100	4,466,300,451	12.53

Table 6.11, Continued

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
Urban Other Principal Arterial FHWA Code : 14			
1990	6,942,200,000	7,363,950,625	-6.08
1991	7,205,000,000	7,418,867,913	-2.97
1992	8,077,963,620	7,430,968,152	8.01
Rural Minor Arterial FHWA Code : 06			
1990	5,590,000,000	5,025,890,680	10.09
1991	5,617,000,000	5,063,371,687	9.86
1992	3,934,000,000	5,071,630,091	-28.92
Urban Minor Arterial FHWA Code : 16			
1990	5,239,000,000	5,360,794,025	-2.32
1991	5,440,000,000	5,400,772,602	0.72
1992	5,493,689,095	5,409,581,310	1.53
Rural Major Collector FHWA Code : 07			
1990	8,749,000,000	8,637,018,287	1.28
1991	8,369,000,000	8,701,429,585	-3.97
1992	8,937,834,935	8,715,621,694	2.49

A possible explanation for why some functional classes have an absolute percent difference less than five percent while others are greater than five percent is that, the short-term VMT model at this stage does not account for changes in mileage of functional classes due to reclassification of roads. Sometimes roads are upgraded to carry higher volumes, which may lead to reclassification in higher functional classes. This causes a reduction in mileage for one class with a corresponding increase in road mileage for some other class.

The FHWA estimates for Indiana are obtained from INDOT, whose VMT estimation method is dependent on traffic count and centerline mileage. Significant changes in road mileage from year to year may therefore cause significant changes in VMT for the functional classes concerned.

This point is well illustrated by taking a close look at the mileage of the various functional classes presented in Table 6.12. Functional classes with an absolute percent difference of less than five percent (see Table 6.11) have very little change in road mileage open to traffic, and functional classes with an absolute percent difference greater than five percent have significant changes in functional class mileage. For example, rural minor aterials have absolute percent differences of 10.09, 9.86, and 28.92 for the three years -- 1990, 1991, and 1992 -- (see Table 6.11) respectively. In Table 6.12 it will be noted that for the years 1990 and 1991, there is a 1 mile difference in functional class mileage with the absolute percent differences for the two years approximately 10 percent. The absolute percent difference for 1991 and 1992 are approximately 10 and 29 percent respectively, the functional class mileage change is from 1991 to 1992 is 813 miles. This significant change in mileage caused the absolute percent difference to change from 10 percent to 29.

The results of model calibration and validation indicate that, even though the short-term VMT model SHORTVMT is well calibrated to predict total statewide VMT for Group X, errors may be encountered in the prediction of statewide VMT for the functional classes in Group X in situations of reclassification of roads into other functional classes. The SHORTVMT model thus, must be recalibrated to control errors that may be introduced by significant changes in functional class mileage due to reclassification of roads even though the total state network mileage may not change significantly.

6.2.6 Final Model Calibration

Because roads are sometimes reclassified to conform to FHWA requirements regarding geometrics and traffic volume in the state network, functional class mileage sometimes changes significantly after reclassification, while the overall state network mileage may change very little. This may cause significant errors in the prediction of functional class VMT using the calibrated model presented in Section 6.2.4. Researchers in this study recalibrated the short-term VMT model to control for errors that may be introduced by reclassification in the future by applying correction factors to the statewide VMT of each functional class, depending how its statewide mileage is affected by reclassification of roads in the state network. Equation 6.3 illustrates the variables in the correction factors.

$$FCCF_{ij} = (FCMI_{ij} * GXTMMI / (FCMMI_i * GXTMI_j) \quad \ldots\ldots\ldots\ldots (6.3)$$

where

$FCCF_{ij}$	is the reclassification correction factor for functional class i in Group X for year j.
$FCMMI_i$	is the average statewide mileage for functional class i in Group X. This is estimated from functional class i mileage for 1990,1991, and 1992. See Table 6.12.
$FCMI_{ij}$	is the statewide mileage for functional class i in Group X for year j.
GXTMMI	is the total of the average statewide mileage of all functional classes in Group X, which is 19,166. See Table 6.12.
$GTMI_j$	is the total statewide mileage of all functional classes in Group X for year j.

The reclassification correction factor $FCCF_{ij}$ is calculated automatically in Sheet 5 of SHORTVMT for each functional class and applied to each functional class VMT in Group X to obtain the corrected VMT for the respective functional class. A typical representation of the correction factors can be found in Table A-5 (Appendix A) for 1991, based

Table 6.12 Functional class mileage open to traffic for Group X functional classes in 1990, 1991, and 1992 [11, 12, 36].

Functional Class	FHWA Code	Statewide Functional Class Mileage (miles)			
		1990 A	1991 B	1992 C	*Average (A+B+C)/3
Interstates- Rural	01	863	863	822	849
Interstates- Urban	11	285	274	317	292
Freeways and Expressways (Principal Arterial) -Urban	12	112	114	115	114
Other Principal Arterial - Rural	02	1,102	1,103	1,655	1,287
Other Principal Arterial - Urban	14	1,346	1,352	1,533	1,410
Minor Arterial - Rural	06	3,134	3,135	2,322	2,864
Minor Arterial - Urban	16	2,288	2,277	2,423	2,329
Major Collector - Rural	07	9,754	9,773	10,536	10,021
Total for Group X		18,884	18,891	19,723	19,166
Statewide Total Network Mileage		91,908	92,029	92,019	91,985

* Functional class mileage used in SHORTVMT for control of errors due reclassification of functional classes in Group X.

on data in Table A-2 (from Table 6.12).

6.2.7 Final Model Validation

The final validation of SHORTVMT comes after final calibration to control errors that may be introduced by reclassification of roads into new functional classes. This process follows exactly the process described in Section 6.2.5, including the evaluation criteria using the absolute percent difference (equation 6.2). The short-term VMT is modified at this stage to include data on statewide mileage for each functional class, which is used in the computations of the correction factors, thus the mileage for each functional class presented in Table 6.12 for 1990 through 1992 are used in Sheet 1(B) along side Alternative A input data in Table 6.4.

Statewide VMT estimates from Highway Statistics and from the recalibrated short-term VMT model were compared in the model evaluation process. The first comparison involves the comparison of the total of all statewide VMT estimates for all functional classes in Group X from 1990 through 1992. The percent differences for this comparison are presented in Table 6.13. The signs of the percent difference values presented in the table are noted to be negative and positive indicating that the final calibrated model neither consistently over-estimates nor underestimates the total Group X statewide FHWA VMT estimate. The absolute percent differences are found to be less than 2 percent for all three years -- 1990, 1991 and

1992. The recalibration is noted to have caused slight increases in absolute percent differences. However, these increases are considered negligible, because the absolute differences are still less than 2 percent. This is an indication that the recalibrated short-term VMT model SHORTVMT is still well calibrated to predict total statewide VMT for Group X.

The second comparison involves the comparison the statewide VMT estimates for each functional class in Group X for FHWA estimates and estimates obtained from the short-term VMT model. The percent differences, together with the VMT estimates used to compute the absolute differences, are presented in the table. The signs of the percent difference values presented in Table 6.14 are noted to be positive and negative. This indicates that the model is neither consistently overestimating nor underestimating the FHWA's VMT estimates for functional classes in Group X. The absolute percent differences together with the VMT estimates used to compute the absolute differences are presented in Table 6.14. The absolute percent differences for six functional classes namely, rural interstates, urban interstates, urban minor arterial, rural major collector, rural minor arterial, and urban Other Principal Arterial were found to be less than 5 percent for all three years -- 1990, 1991 and 1992. Thus it can be stated that the recalibrated model has increased the number of functional classes that have absolute percent differences less than 5 percent from four to six. This is an indication that the recalibrated model in Section 6.2.7 is a better model than the first calibrated model in Section 6.2.5. The absolute percent differences for two functional classes -- urban freeways and expressways, and rural other principal arterials -- were found to be less than 9 percent for both classes, except for the 1992 difference for urban freeways and expressways of 22.74 percent. There is no clear explanation for such a high value of absolute percent difference in 1992 for urban freeways and expressways after controlling for errors due to reclassification. Future Highway Statistics statewide VMT estimates from 1992, compared with SHORTVMT statewide estimates may provide some clue to this single high value of absolute percent difference. A comparison of the absolute percent differences for the calibrated SHORTVMT -- Tables 6.10 and 6.11 -- and those obtained for the recalibrated SHORTVMT -- Tables 6.13 and 6.14 -- show the recalibrated SHORTVMT to control reasonably well prediction errors due to reclassification. Even though there are some functional classes with higher absolute percent differences for the recalibrated case, these are within 1 to 2 percent. However, it will be noted that there are some significant reductions in absolute percent differences with the use of the recalibrated model. Decreases ranging from 1 percent to 28 percent difference in general were observed in comparing absolute percent differences of the calibrated model in Section 6.2.5 with those from the recalibrated model in Section 6.2.7 (see Tables 6.11 and 6.14). A typical example

Table 6.13 Comparison of Group X statewide VMT estimates from FHWA with SHORTVMT estimates after final calibration.

Year	Total Statewide VMT Estimates for Group-X (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
1990	43,486,000,000	42,765,672,358	1.66
1991	43,759,000,000	43,922,576,803	1.91
1992	44,382,088,195	44,895,096,925	-1.16

Table 6.14 Comparison of Group X statewide VMT estimates from FHWA with SHORTVMT estimates for functional classes in Group X after final calibration.

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
Rural Interstates FHWA Code : 01			
1990	6,640,000,000	6,791,882,425	-2.29
1991	6,943,000,000	6,841,789,946	1.46
1992	6,577,614,995	6,528,083,685	0.75

Table 6.14, Continued

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
Urban Interstates FHWA Code : 11			
1990	5,279,000,000	5,150,729,616	2.43
1991	5,104,000,000	4,988,316,865	2.27
1992	5,544,637,985	5,781,195,910	-4.27
Urban Freeways and Expressways FHWA Code : 12			
1990	923,000,000	841,625,127	8.82
1991	949,000,000	862,948,939	9.07
1992	710,456,805	872,033,247	-22.74
Rural Other Principal Arterial FHWA Code : 02			
1990	4,124,000,000	3,788,401,098	8.14
1991	4,132,000,000	3,819,701,710	7.56
1992	5,105,890,100	5,741,255,699	-12.44

Table 6.14, Continued

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"SHORTVMT"	
Urban Other Principal Arterial FHWA Code : 14			
1990	6,942,200,000	7,027,102,987	-1.23
1991	7,205,000,000	7,110,293,493	1.31
1992	8,077,963,620	8,076,216,369	0.02
Rural Minor Arterial FHWA Code : 06			
1990	5,590,000,000	5,497,668,128	1.65
1991	5,617,000,000	5,539,832,708	1.37
1992	3,934,000,000	4,010,326,065	-1.94
Urban Minor Arterial FHWA Code : 16			
1990	5,239,000,000	5,264,476,069	-0.49
1991	5,440,000,000	5,277,664,074	2.98
1992	5,493,689,095	5,625,836,183	-2.41
Rural Major Collector FHWA Code : 07			
1990	8,749,000,000	8,403,786,907	3.95
1991	8,369,000,000	8,482,029,068	-1.35
1992	8,937,834,935	9,160,149,767	-2.49

is the absolute percent values for the rural minor arterial. The change in absolute percent differences is from 28.92 percent to 1.94 percent. This shows that the introduction of the correction factor into the calibrated SHORTVMT to control for errors due to reclassification improves the predictive capabilities of the model. Another advantage of introducing Group X functional class mileage into the model is that it will provide future VMT estimates for Group X roads after any planned reclassification.

6.3 Chapter Summary

This chapter covered a detailed description of the non-traffic count-based short-term statewide VMT forecasting model developed in this study for predicting short-term statewide VMT for Indiana. The VMT forecasts generated by the model are dependent on forecasts of the distribution of licensed in the state of Indiana with respect to sex and age and their driving behavior. Also discussed is the two-step model calibration and validation process carried out to enable the non-traffic count based VMT forecasting model generate traffic count-based VMT forecasts with respect to all functional classes in the state network. The traffic count-based VMT estimates expected from the calibrated model include a combined VMT estimate for the neglected functional classes -- minor collectors, urban collectors, and local roads -- which have inadequate traffic data in the state road inventory, on which INDOT relies for traffic data in VMT estimation.

Model-generated statewide VMT estimates for the years 1990 through 1992, which are noted to be approximately 12 percent less than FHWA's VMT estimates, are discussed. The most likely model-generated statewide VMT forecasts from 1993 through 1996, which is the main objective of this study, are discussed.

CHAPTER 7

THE STATEWIDE VMT TRACKING MODEL

7.1 Introduction

This chapter covers the detailed description of the second of two disaggregate cross classification statewide VMT models developed in this study. The model is programmed into a QUATTRO PRO spreadsheet and named TRACKVMT. TRACKVMT consists of five subsidiary spreadsheets. The five spreadsheets play different roles in the model, from the input data sheets (Sheet 1A and Sheet 1B) through Sheet 4, which contains the final product of statewide VMT forecast with respect to FHWA functional classes. This chapter discusses the use of TRACKVMT to estimate VMT for 1990 as a demonstration of how this model is used for VMT estimation for Indiana.

7.2 Model Description

The statewide VMT tracking model is designed to track the short-term VMT forecasts obtained from SHORTVMT. The statewide VMT tracking model is simply a modified form of the final calibrated short-term statewide VMT model -- SHORTVMT.

The difference between the VMT tracking model and the short-term VMT model is the input data requirements. While SHORTVMT relies on population forecasts and assumptions relating to driver licensing to produce forecasts of licensed drivers with respect to sex and age category, the VMT tracking model requires the actual distribution of licensed drivers with respect to sex and age category that are published in Highway Statistics annually. The statewide VMT tracking model is programmed into a spreadsheet named "TRACKVMT". The TRACKVMT spreadsheet program contains five separate spreadsheets, which are presented in Tables B-1(A) through B-5 in Appendix B. The location of each spreadsheet in TRACKVMT can be found in the last row of each table in Appendix B. Each sheet performs a unique function leading to statewide VMT estimates with respect to functional classes in the state road network in Indiana. Sheet 1(A) and Sheet 1(B) deal with handling input data. Sheet 5 is where the final product of statewide VMT forecasts with respect to FHWA functional classes are obtained. Information on instant macro commands for printing the results in all five sheets including Sheet 2 after each run of the program is available in Sheet 2 .

7.2.1 Assumptions Supporting the Statewide VMT Tracking Model

The VMT tracking model is a modified version of the short-term VMT model and the assumptions stated in Section 6.2.1 also hold for TRACKVMT.

7.2.2 Description of the VMT Tracking Model

The input data required to run TRACKVMT model are listed below with respect to the sheet in which they are required in TRACKVMT:

Sheet 1(A) in Table B-1.

1. The actual number of licensed drivers registered in the State of Indiana with respect to sex and age category.

Sheet 1(B) in Table A-1

2. The mileage for functional classes in Group X.

Input data on licensed drivers required in item 1 above are published annually in Highway Statistics. These numbers may be compared with the forecasts of licensed drivers for the year whose VMT is being tracked. This provides opportunity for evaluating the forecasting capabilities of the short-term VMT model. For example, if the distribution of Indiana licensed drivers published in Highway Statistics vary considerably from the forecasted distribution obtained from SHORTVMT, this may be an indication of poor performance of the short term model. Variations in the distribution of licensed drivers published in Highway Statistics may prompt the need to modify assumptions supporting the forecasts or recalibration of the short-term VMT model. The input data in Sheet 1(A) is carried over into Sheet 3 -- in Table B-3 -- which is the equivalent of Sheet 4 -- in Table A-4 -- in SHORTVMT. From this point, the VMT estimation process through Sheet 4 -- in Table B-4 -- is the same as the VMT estimation process described in Section 6.2.2.

7.3 Statewide VMT Estimation for 1990 Using TRACKVMT

This section concerns the use of the statewide VMT tracking model to estimate statewide VMT for 1990 as a demonstration of how TRACKVMT operates.

The distribution of licensed drivers used in Sheet 1(A) for 1990 (see Tables B-1 and 4.7) are obtained from Highway Statistics [12]. The functional class mileage used in Sheet 1(B) for 1990 (see Tables B-2 and 6.12) are obtained from Highway Statistics [12]. The TRACKVMT model statewide VMT estimates obtained from TRACKVMT for the year 1990 can be found in Sheet 4 (see Table B-4).

7.4 Comparison of TRACKVMT Statewide VMT Estimates with FHWA Indiana Estimates for 1990

The comparison of statewide VMT estimates obtained from TRACKVMT with estimates published in Highway Statistics for 1990 are presented in Tables 7.1 and 7.2. The statewide VMT estimates from Highway Statistics and TRACKVMT model for 1990 are compared using the absolute percent difference criterion which is discussed in Section 6.2.5 of this document.

The first comparison involves the comparison of the total Group X statewide VMT estimates for 1990. The absolute percent difference for this comparison are presented in Table 7.1. The absolute percent difference in Table 7.1 is found to be less than 2 percent for 1990. This indicates that the short-term VMT model SHORTVMT is well calibrated to predict total statewide VMT for Group X.

The second comparison involves the comparison of FHWA's VMT estimates for functional classes in Group X with corresponding estimates obtained from TRACKVMT. The absolute percent differences, together with the VMT estimates used to compute the absolute percent differences, are presented in the table. The absolute percent differences for six functional classes -- rural interstates, urban interstates, urban minor arterials, rural minor arterials, urban other principal arterials, and rural major collectors -- are found to be less than 5 percent. The absolute percent differences for two functional classes -- urban freeways and expressways, rural other principal arterials, and rural minor arterials -- are found to be approximately 9 and 8 percent respectively for 1990. The percent differences in Tables 7.1 and 7.2 are noted to be negative and positive. This indicates that TRACKVMT neither consistently overestimates nor underestimates the FHWA statewide VMT. The maximum percent difference (absolute) is noted to be less than 10 percent (see Tables 7.1 and 7.2) for TRACKVMT. TRACVMT may thus be considered well calibrated in the jugdement of the researchers in this study to predict statewide VMT with respect to functional classes in the Indiana state road network .

Table 7.1 Comparison of Group X statewide VMT estimates from FHWA with TRACKVMT estimates for 1990.

Year	Total Statewide VMT Estimates for Group-X (annual miles)		Percent Difference (%)
	FHWA	Model-"TRACKVMT"	
1990	43,486,000,000	42,709,873,762	-1.78

Table 7.2 Comparison of Group X statewide VMT estimates from FHWA with TRACKVMT estimates for functional classes in Group X for 1990.

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"TRACKVMT"	
Rural Interstates FHWA Code : 01			
1990	6,640,000,000	6,783,020,703	2.15
Urban Interstates FHWA Code : 11			
1990	5,279,000,000	5,144,009,191	-2.56

Table 7.2, Continued

Year	Functional Class Statewide VMT Estimate (annual miles)		Percent Difference (%)
	FHWA	Model-"TRACKVMT"	
Urban Freeways and Expressways FHWA Code : 12			
1990	923,000,000	840,527,015	-8.94
Rural Other Principal Arterial FHWA Code : 02			
1990	4,124,000,000	3,783,458,174	-8.26
Urban Other Principal Arterial FHWA Code : 14			
1990	6,942,200,000	7,017,934,3621	1.09
Rural Minor Arterial FHWA Code : 06			
1990	5,590,000,000	5,490,495,035	-1.78
Urban Minor Arterial FHWA Code : 16			
1990	5,239,000,000	5,257,607,233	0.36
Rural Major Collector FHWA Code : 07			
1990	8,749,000,000	8,392,822,050	-4.07

7.5 Chapter Summary

Discussed in this chapter is a detailed description of the model developed for use in tracking statewide VMT forecasts obtained from the short-term VMT model. TRACKVMT and SHORTVMT are very similar in structure. Both models are supported by the same theories and assumptions, the only difference being input data requirements. As a demonstration of the estimating capabilities of TRACKVMT and how it operates, TRACKVMT is used to estimate statewide VMT in Indiana for 1990. Statewide VMT estimates for Indiana obtained from TRACKVMT for 1990 for the various functional classes in the state road network were compared with FHWA VMT estimates for corresponding functional classes using the absolute percent difference criteria. The maximum absolute percent difference obtained comparing the FHWA and TRACKVMT estimates is noted to be 9 percent, which is reasonable in the judgement of the researchers in this study. This is an indication that TRACKVMT is well calibrated to generate reasonable estimates of statewide VMT estimates for functional classes in the state network. Like SHORTVMT, TRACKVMT generates combined statewide VMT estimates for the Group Y functional classes neglected in the state road network -- minor collectors, urban collectors, and local roads (see Section 6.2.4).

CHAPTER 8

USER MANUAL FOR COMPUTER PROGRAMS

8.1 Introduction

This chapter will describe how to use the two separate QUATTRO PRO spreadsheet programs named SHORTVMT and TRACKVMT. SHORTVMT and TRACKVMT have been written to allow for easy and efficient execution of the disaggregate cross classification short term VMT forecasting and the VMT tracking models, respectively. The programs are not written to operate as "stand alone" software; they are intended to be used within the QUATTRO PRO spreadsheet environment. All the QUATTRO PRO keystrokes are available to the user, and the user is expected to use some of the keystrokes during certain times while running the programs. Users of these spreadsheet programs are expected to have a working knowledge of QUATTRO PRO.

8.2 System Requirements

The two spreadsheet programs SHORTVMT and TRACKVMT require QUATTRO PRO version 4.0 or higher to operate. The QUATTRO PRO program should be installed on IBM-compatible computer system as described in the QUATTRO PRO User Manual.

8.3 Running the Programs

The procedures involved in running the two spreadsheet programs have been designed to be the same to simplify operation of the programs. For example, in both programs, the two input data sheets -- Sheet 1(A) and Sheet 1(B) -- are located in approximately the same area. Also, instant macro commands may be found in Sheet 2 of both programs. Hard copies of Sheet 2 may be obtained from either program by simultaneously pushing the "ALT" and "M" keys on the keyboard of the computer.

8.3.1 Location of Spreadsheets in SHORTVMT and TRACKVMT

The location of subsidiary spreadsheets in SHORTVMT and TRACKVMT are discussed in this section. SHORTVMT contains six subsidiary spreadsheets, and TRACKVMT five subsidiary spreadsheets. The location of the subsidiary spreadsheets in the two programs can be found in the last row of the tables in Appendices A and B for SHORTVMT and TRACKVMT, respectively. For example, the location of Sheet 1(A) in SHORTVMT is presented in the last row of Table A-1 in Appendix A as A1..D14 (see Table A-1). This simply means that this subsidiary spreadsheet is located within the region enclosed by the columns A and D and rows 1 and 14. The programs are designed such that, once the programs are loaded pressing the "Home" key on the keyboard the cursor relocates to cell A1 into the input data sheet (Sheets 1(A)). This is to facilitate operation of the programs during sensitivity analyses, where a user may need to change a predictor variable value more than once.

8.3.2 Data Required to Run the Programs

Information required to run SHORTVMT can be found in Tables A-1 and A-2 and in Tables B-1 and B-2 in TRACKVMT. Suggested sources of input data required to run SHORTVMT and TRACKVMT are discussed in Sections 6.2.3 and 7.3, respectively, of this document.

To ensure that users of the programs enter the required data in the appropriate cells in the input data sheets -- Sheets 1(A) and Sheets 1(B) -- the cells have been clearly labelled. Each value should be entered into the cell that is immediately to the right of the label cell (see Tables A-1,-A -

2, B-1, and B-2). The user is encouraged to use the "Page-Up" and Page-Down" keys to move from one cell to another in each data input sheet.

The two spreadsheet programs have been served as protected spreadsheet files. This simply means that, data may only be entered into the spreadsheets through certain cells. Depending on how the spreadsheets have been configured by the user, unprotected cells may be identified as cells that are noticeably different in color from the protected cells. If the user tries to enter data into a protected cell, the program will "beep" and display an error message. The user is encouraged to make sure that the protection options remain in effect whenever the programs are being used. If the protection is turned off, it is possible that sections of the program may be unintentionally erased.

After the input data are entered into the appropriate cells, the program automatically calculates the statewide VMT estimates, including estimates of traffic count-based statewide VMT estimates with respect to functional classes in the state road network. (See Tables A-5 and B-4 for SHORTVMT and TRACKVMT, respectively)

8.3.3 Saving Results of VMT Forecast obtained from the Programs

Because all calculations are done within the QUATTTRO PRO environment, it is difficult to save the output to disk. The user may save the results and spreadsheet program using the "/ File Save" keystrokes. This will save the entire spreadsheet file in both SHORTVMT and TRACKVMT.

8.3.4 Printing Results of VMT Forecast obtained from the Programs

Instant macro commands have been coded into the two spreadsheet programs -- SHORTVMT and TRACKVMT -- to enable easy printing of hard copies of all subsidiary sheets in each program. The instant macro commands needed to print each sheet in the two programs may be found in Tables A-6 and B-5 for SHORTVMT and TRACKVMT, respectively. Hard copies of each sheet in each program will be produced at a default printer on activation of the instant macro command. For example, to obtain a hard copy of Sheet 5 in SHORTVMT, the user simultaneously presses the "ALT" and "E" keys, and a hard copy of Sheet 5 will be produced at the default printer assigned to the computer being used at the time of running the program. The user is encouraged to refer to Tables A-6 and B-5 for information on the instant macro commands provided with the two programs. Hard copies of the instant macro commands may be obtained while running the programs by pressing the "ALT" and "M" keys simultaneously. The commands are not case sensitive, which means the use of upper case or lower case letters should have no effect on the program. Should the user decide not to use the instant macro commands, the user may refer to the QUATTRO PRO User Manual to understand fully the QUATTRO PRO keystroke option available for printing.

8.4 Chapter Summary

This chapter discussed the basic structure and operation of the two spreadsheet programs, SHORTVMT and TRACKVMT, which have been coded to operate within the QUATTRO PRO environment. Also discussed are the special instant macro commands provided with the programs to enable easy use of the programs with respect to obtaining quick hard copies of the subsidiary sheets in the programs by bypassing the keystrokes option provided in QUATTRO PRO for printing.

CHAPTER 9

CONCLUSION

9.1 Introduction

This study was undertaken to review and develop statewide VMT estimation procedures for INDOT to make possible improved statewide VMT estimates in Indiana. INDOT's VMT estimation procedure is traffic count-based and conforms to EPA [20] and FHWA [11] requirements for VMT estimation. However, INDOT is uncomfortable with the statewide VMT estimates obtained for three functional classes, namely, minor collectors, urban collectors, and local roads, because of inadequate traffic data available for the estimation of VMT on these functional classes. These functional classes have inadequate traffic data because they are not part of the state road inventory. Hence, the statewide VMT estimate, which is expected to include all roads in the state road network, includes estimates that are bound to be inaccurate. In this study, non traffic count-based VMT estimation procedures are developed based on the distribution of licensed drivers and their driving behavior to provide INDOT with VMT estimates from an independent source. Two cross-classification models are developed in this study. One model is designed to forecast short-term statewide VMT in Indiana and the second model to track annually the short term VMT estimates obtained from the short-term VMT forecasting model. The two models are calibrated to transform the non traffic count-based statewide VMT estimate into statewide VMT estimates with respect to functional classes in the state road network. The estimates generated by the calibrated models include combined VMT estimates for functional classes neglected in the state road inventory. The advantage of INDOT having an independent VMT source is to permit the generation of statewide VMT estimates for comparison with current methods' estimates, particularly for those functional classes whose VMT estimates are based on inadequate traffic data.

9.2 Summary of Findings

The two models developed in this study are the short-term statewide VMT forecasting model for Indiana and the short-term VMT forecasts tracking model. The models are programmed into QUATTRO PRO spreadsheets and named SHORTVMT and TRACKVMT (see Appendices A and B). Spreadsheet programs allow easy and efficient execution of the models, and are very convenient for the implementation of disaggregate cross-classification models. The spreadsheet programs were used to generate statewide VMT estimates for Indiana for the years 1990 through 1996. The primary reason for doing this was to find out how the statewide VMT estimates generated from the models compare with INDOT traffic count-based statewide VMT estimates.

9.2.1 Short-Term VMT Model

The short-term VMT model uses non-traffic data such as the forecast of state population distribution, assumptions that most likely describe the future population of licensed drivers (see Tables A-1), and functional class mileage for roads with adequate traffic counts (see Tables A-2) to generate short-term statewide VMT forecasts. Table A-5 shows a typical format for the results obtained from the model.

The short-term VMT model is used in this study to forecast statewide VMT for Indiana from 1990 through 1996 (see Table 6.5). The statewide VMT estimates from 1990 through 1992 were compared with INDOT's VMT estimates for the same period -- 1990 through 1992. The comparison showed that the model-generated total statewide VMT estimates were approximately 12 percent lower than INDOT's traffic count-based estimates. The difference was attributed to a possible overestimation of VMT for the functional classes with inadequate traffic data -- minor collectors, urban collectors, and local roads. Model-generated statewide VMT estimates for functional classes with adequate traffic data (Group X functional classes in this study) were compared with INDOT's estimates for corresponding functional classes for the period 1990 through 1992. The comparison is briefly discussed in Section 9.2.3.

9.2.2 VMT Tracking Model

The VMT tracking model is a modified form of the short-term VMT forecasting model. The main difference between the two models is input data requirements. While the short-term VMT model forecasts the distribution of Indiana licensed drivers with respect to sex and age category (see Section 9.2.1), the VMT tracking model requires the "actual" distribution of Indiana licensed drivers published in Highway Statistics [12] for use in the cross classification models.

To evaluate the performance and demonstrate the operation of the VMT tracking model, the model is used in this study to estimate 1990 statewide VMT with respect to functional classes in the state road network. The input data used to estimate the 1990 statewide VMT are listed below.

1. The "actual" distribution of licensed drivers with respect to sex and age category (see Table B-1)
2. The functional class mileage for roads with adequate counts (Group X functional classes, see Table B-2)

The input data listed above were obtained from the 1990 Highway Statistics. Table B-4 shows the statewide VMT estimates obtained using the input data listed above for 1990. This presents a typical format of results expected from this model.

Model-generated statewide VMT estimates for functional classes with adequate traffic data (Group X functional classes in this study) were compared with INDOT's estimates for corresponding functional classes for 1990. The comparison is briefly discussed in Section 9.2.3.

9.2.3. Evaluation of models

One important aspect in developing forecasting models is the evaluation of calibrated forecasting models for accuracy. Inaccurate forecasts may lead to inaccurate and misleading policy and programming decisions. Because forecasted values cannot be tested against their future values, the procedure known as "backforecasting" is commonly used to "forecast" known results. This procedure is used in this study to compare model-generated statewide VMT estimates for functional classes with adequate traffic data (Group X functional classes in this study) with INDOT's estimates for corresponding functional classes.

In this study, traffic count-based statewide VMT estimates were used in the calibration of the models developed in this study. As discussed in Section 9.2.1, the short-term VMT model is used to forecast statewide VMT for the years 1990 through 1992, and the VMT tracking model is used to estimate VMT for 1990 using information published in the 1990 Highway Statistics. The performance measure used in the evaluation process is percent difference (see Section 6.2.5). Using this performance measure, model-generated VMT forecasts are compared with FHWA estimates to investigate how close model-generated estimates are to the FHWA estimates. The closer the percent difference is to zero, the better the prediction of FHWA estimates.

For the short-term model, 78 percent of all the percent absolute difference values presented in Tables 6.13 and 6.14 (between FHWA estimates and those from the final calibrated model) for the years 1990 through 1992 are less than 5 percent. This shows that the short-term model's predictions are reasonably close to the FHWA most of the time. The signs associated with the percent difference values in the tables are also noted to be negative and positive for the functional class predictions. This indicates that the short-term model neither consistently underestimates nor overestimates with respect to FHWA values. However, the Group X total in Table 6.13 is consistently underestimated by the model, but with a maximum percent difference value of 2 percent that, in the opinion of the researchers, is considered negligible. Similar results were noted for the VMT tracking model, based on Tables 7.1 and 7.2 for 1990 only.

9.3 Problems, Limitations, and Suggestions

The models developed in this study are based on data from NPTS and Highway Statistics that are specific to Indiana. Therefore, the models should only be used to forecast VMT on Indiana highways. However, procedures similar to those in this study may be adopted to develop similar models for other states or regions.

Because these are forecasting models, one must understand that model-generated forecasts are only as accurate as the input data and assumptions made about the future distribution of licensed drivers in the state of Indiana. Estimates of average annual miles driven with respect to sex and age category (see Tables A-3 and B-2) in the models are based on the 1990 NPTS. These estimates are assumed constant to 1996. The next NPTS is scheduled for 1995, and the survey data are expected to be available in 1996. The 1995 NPTS data may be used in updating the models. Also, information on the distribution of Indiana licensed drivers published each year in Highway Statistics may be compared with the distribution of licensed drivers generated by the short-term model. This is a simple and effective way of annually evaluating the forecasting capabilities of the short-term model.

It is important that the most current predictor variables be used in the models to guard against inaccurate forecasts.

Lastly, the results of these models must be approached as estimates, not actual values. Professional judgment must be applied to each forecast generated by the models. Each forecast should be carefully reviewed by the forecaster before any final recommendations and conclusions are made from model-generated statewide VMT forecasts.

9.4 Suggestions for Future Research

Future research in developing VMT forecasting models is encouraged, because the models provide INDOT with an alternative source of VMT estimates to supplement INDOT's estimates. These models should be updated as future data become available. The models developed in this study should be continually monitored and updated when needed to ensure that the model-generated VMT estimates remain as accurate as possible. The QUATTRO PRO spreadsheet programs have been written to allow for easy updating of the models.

A long-term cross-classification VMT model originally planned for this study was not developed. This was due to unavailability of data specific to Indiana in NPTS surveys prior to 1990. Statistical tests were conducted in exploring the possibility of using national data in a long-term model for Indiana. The tests did not support the use of the national data in the long-term model for Indiana if accurate results were to be expected from the model. Future NPTS data are expected to contain specific data on Indiana that could be used in the development of a long-term VMT model. The short-term VMT model is designed to be used in conducting five-year forecasts. The long-term VMT model would be designed to predict VMT beyond 5 years.

9.5 Conclusions

The primary objective of this study was to provide INDOT with a new method and models that would improve statewide VMT estimation for Indiana. Two simple, fast and inexpensive cross-classification models implemented in QUATTRO PRO spreadsheets were developed in this study based on reliable and readily available data sources. The non traffic count-based VMT forecasting models -- a short-term VMT model and a VMT tracking model -- were calibrated to forecast traffic count-based statewide VMT estimates with respect to functional classes in the state network. The models were evaluated and noted to predict within 5 percent of FHWA's traffic count-based VMT estimates most of the time. It was noted also that the models neither consistently underestimated nor over-estimated FHWA's estimates.

The programs are simple to use and provide forecasters with statewide VMT estimates with a minimum of data input supplied by the user.

LIST OF REFERENCES

LIST OF REFERENCES

1. United States Environmental Protection Agency Air and Radiation Office, Memorandum from Phil Lorang, Subject: "State/Local Concerns and Questions About VMT-Related Aspects of Estimating The 1990 Highway Vehicle Inventory". Ann Arbor, Michigan. July 1992.

2. Federal Highway Administration, Highway Functional Classification. Concepts, Criteria, and Procedures. Washington, D.C. March 1989.

3. Hawthorn, Gary, "Transportation provisions in the Clean Air Act Amendments of 1990" ITE Journal, Institute of Transportation Engineers April 1992, pp 17-24.

4. Erlbaum, Nathan S, "Estimated County Level Vehicle Miles of Travel", Data Services Bureau Report, New York State Department of Transportation, Planning Division, New York, April 1989.

5. Federal Highway Administration, Traffic Monitoring Guide, Washington, D.C., June 1985.

6. Federal Highway Administration, Highway Performance Monitoring System Field Manual, Washington, D.C., December 1987.

7. Federal Highway Administration, Highway Performance Monitoring System Field Manual, Washington, D.C., July 1988.

8. Federal Highway Administration, Highway Performance Monitoring System Field Manual, Washington, D.C., April 1989.

9. Federal Highway Administration, Highway Performance Monitoring System Field Manual, Washington, D.C., April 1990.

10. Federal Highway Administration, Highway Performance Monitoring System Field Manual, Washington, D.C., February 1993.

11. Federal Highway Administration, 1991 Highway Statistics, Washington, D.C., 1993.

12. Federal Highway Administration, 1990 Highway Statistics, Washington, D.C., 1992.

13. Federal Highway Administration, Highway Statistics (Summary to 1985), Washington, D.C., 1987.

14. Federal Highway Administration, Highway Functional Classification, Concepts, Criteria, and Procedures, Washington, D.C., March 1989 (Revised).

15. Federal Highway Administration. Users's Guide for Public Use Tapes, 1990 Nationwide Personal Transportation Survey, Washington, D.C., December 1991.

16. Federal Highway Administration, Users's Guide for Public Use Tapes. 1983-1984 Nationwide Personal Transportation Survey, Washington, D.C., November 1985.

17. Federal Highway Administration, Users's Guide for Public Use Tapes, 1977 Nationwide Personal Transportation Survey, Washington D.C., April 1980.

18. Federal Highway Administration, Highway Travel Forecasts, Washington, D.C., November 1974.

19. Federal Highway Administration, "The Future National Highway Program 1991 and Beyoud, Trends and Forecasts of Highway Passenger Travel", Working Paper No. 2,Washington, D.C., December 1987.

20. United States Environmental Protection Agency, EPA Section 187, VMT Forecasting and Tracking Guidance, January 1992.

21. Joint Highway Research Project Study Advisory Commitee Meeting, Subject: "Statewide Vehicle-Miles Travelled in Indiana", December 18, 1992.

22. Lombard, Paulus C., "An Analysis of Truck Traffic in Indiana", Master's Thesis, School of Civil Engineering, Purdue University, December 1989.

23. Clark, David Emory, "Updating Models to Forecast Traffic Volumes on Rural Segments of the State Highway System", Master's Thesis, School of Civil Engineering, Purdue University, May 1983.

24. Greene, David L., "Long-Run Vehicle Travel Prediction from Demographic Trends", Transportation Research Record 1135, pp 1-9.

25. SAS Institute Inc. SAS System, Version 6. SAS Institute, Cary, North Carolina, 1991.

26. SAS Institute Inc. SAS User's Guide: Statistics Version 5 Edition, SAS Institute Inc., Cary, North Carolina, 1991.

27. Netter, J., Wasserman, W., and Whitmore, G.A., Applied Statistics, (Third Edition), 1988.

28. Meyer M.D. and Miller E.J., Urban Transportation Planning, A Decision-Oriented Approach, McGraw-Hill Inc., 1984, pp 244-256.

29. Colman Steven B., and Aronson, Micheal N., "Using Traffic Network Models to Acess Site Impact Traffic", Conference Proceedings of the American Society of Civil Engineers on Site Impact Traffic Assessment, Problems and Solutions, ed. Paaswell Robert E., co-ed. Rouphail N and Sutaria T.C., American Society of Civil Engineers, New York, 1992.

30. North Carolina Department of Transportation, Planning and Research Branch, "Hickory, Newton, Conover Urban Area Throughfare Plan", 1986.

31. Borland Internationsl, Inc., User's Guide: Quattro Pro, Version 4.1, Borland International, Inc., Scotts Valley, California.

32. INDOT, "Road Inventory File," Division of Program Developement, INDOT, 1992.

33. Federal Highway Administration, The Future National Highway Program 1991 and Beyound, Trends and Forecasts of Highway Passeneger Travel, Working Paper No. 2. Washington, D.C., December 1987.

34. Indiana University, Statistical Information System (STATIS), The Economic Development Information Network (EDIN), School of Bussiness, Indiana Business Research Center, Indaiana University,1992.

35. Barbara Eversole, Telephone Communication on problems encountered with the use of the 1977 and 1983 NPTS Public Tapes and future NPTS. August, 1993 through November 1993.

36. Minutes of the Conformity and VMT/TD Modeling Clean Air Sub-Committtee Meeting. Indiana Government Center South Training Center room 12. Thursday, May 21, 1992.

37. Joint Highway Research Proposal. Estimating Statewide Vehicle-Miles Traveled in Indiana. Project No. C-36-54XX. August 12, 1992.

38. Minutes of the Conformity and VMT/TD Modeling Clean Air Sub-Committee Meeting. Indiana Government Center. October 1, 1992.

39. Minutes of the Conformity and VMT/TD Modeling Clean Air Sub-Committee Meeting. October 20, 1992.

40. Kirk Mangold, Telefax Communication on the 1992 Indiana traffic count-based statewide VMT estimates. September, 1993.

41. Joint Highway Research Project Study Advisory Commitee Meeting, Subject: "Statewide Vehicle-Miles Travelled in Indiana", December 15, 1993.

42. Kirk Mangold, Telepone Communication on VMT Estimation on Indiana Local Roads, June 1993.

APPENDICES

Appendix A

Table A.1 Sheet 1(A) in SHORTVMT

SHEET 1 (A)

SHORT-TERM VEHICLE MILES TRAVELED FORECASTING MODEL

MODEL INPUT DATA REQUIREMENTS	
INDIANA POPULATION FORECAST	5,585,500
POPULATION FORECAST YEAR	1991
% OF POP. 16 YEARS AND OVER	77.00
% OF 16 YEARS AND OVER POP AS LICENSED DRIVERS	85.00
% OF LICENSED DRIVERS AS MALES IN INDIANA	51.00
LOCATION OF SHEET 1(A) IN SHORTVMT -- A1..D14	

Table A.2 Sheet 1(B) in SHORTVMT

SHEET 1 (B)

SHORT-TERM VEHICLE MILES TRAVELED FORECASTING MODEL

GROUP X- FUNCTIONAL CLASS MILEAGES		MODEL AVERAGE MILEAGES
RURAL INTERSTATES	863	849
URBAN INTERSTATES	274	292
URBAN FREEWAYS AND EXPRESSWAYS	114	114
RURAL OTHER PRINCIPAL ARTERIAL	1,103	1,287
URBAN OTHER PRINCIPAL ARTERIAL	1,352	1,410
RURAL MINOR ARTERIAL	3,135	2,864
URBAN MINOR ARTERIAL	2,277	2,329
RURAL MAJOR COLLECTOR	9,773	10,021
TOTAL GROUP X MILEAGE	18,891	19,166
TOTAL STATE NETWORK MILEAGE	92,029	91,985

LOCATION OF SHEET 1(B) IN SHORTVMT -- E1..K15

Table A.3 Sheet 3 in SHORTVMT

SHEET 3

SHORT-TERM VEHICLE MILES TRAVELED FORECASTING MODEL

FORECAST OF LICENSED DRIVERS WITH RESPECT TO SEX AND AGE FORECAST YEAR 1991

STATE POPULATION--(INDIANA)	5,585,500
ESTIMATE FOR POP. 16 YRS. AND OVER	4,300,835
ESTIMATE OF TOTAL No. OF LIC. DRVRS	3,655,710
ESTIMATE OF TOTAL MALE LIC. DRVRS	1,864,412
ESTIMATE OF TOTAL FEMALE LIC. DRVRS	1,791,298

AGE GROUP	LICENSED DRIVERS DISTRIBUTION FACTORS		MODEL FORECAST OF LICENSED DRIVERS	
	MALE (%)	FEMALE (%)	MALE (%)	FEMALE (%)
16-19	5.4	5.1	100,678	91,356
20-24	9.7	9.4	180,848	168,382
25-29	12.1	11.9	225,594	213,164
30-34	12.6	12.5	234,916	223,912
35-39	11.3	11.2	210,679	200,625
40-44	9.7	9.8	180,848	175,547
45-49	7.4	7.5	137,966	134,347
50-54	6.0	6.1	111,865	109,269
55-59	5.2	5.3	96,949	95,517
60-64	5.3	5.3	98,814	94,939
65-69	5.0	5.2	93,221	93,147
70-74	4.0	4.2	74,576	75,235
75+	6.4	6.5	119,322	116,434
TOTALS	100	100	1,866,276	1,791,876
COLUMN	(A)	(B)	(C)	(D)

LOCATION OF SHEET 3 IN SHORTVMT -- G16..N47

Table A.4 Sheet 4 in SHORTVMT

SHEET 4

SHORT-TERM VEHICLE MILES TRAVELED FORECASTING MODEL

SHORT-TERM STATEWIDE VMT FORECASTING FOR THE YEAR 1991

AGE GROUP	FORECASTED DISTRIBUTION OF LICENSED DRIVERS		AVERAGE ANNUAL MILES DRIVEN PER LICENSED DRIVER**		STATEWIDE FORECASTS OF VEHICLE MILES TRAVELED		
	MALE (A)	FEMALE (B)	MALE (C)	FEMALE (D)	MALE (E)	FEMALE (F)	TOTAL (G)
16-19	100,678	91,356	12,733	9,580	1,281,936,113	875,192,268	2,157,128,381
20-24	180,848	168,382	18,236	12,985	3,297,943,423	2,186,440,154	5,484,383,577
25-29	225,594	213,164	20,082	12,026	4,530,375,669	2,563,515,502	7,093,891,171
30-34	234,916	223,912	20,754	10,574	4,875,444,766	2,367,647,837	7,243,092,603
35-39	210,679	200,625	16,236	11,002	3,420,576,985	2,207,280,113	5,627,857,097
40-44	180,848	175,547	19,712	10,100	3,564,875,014	1,773,026,540	5,337,901,554
45-49	137,966	134,347	18,916	7,928	2,609,774,049	1,065,105,659	3,674,879,707
50-54	111,865	109,269	18,685	8,549	2,090,213,517	934,087,452	3,024,300,969
55-59	96,949	95,517	17,729	7,057	1,718,863,818	674,059,810	2,392,923,628
60-64	98,814	94,939	15,522	5,366	1,533,831,818	509,475,683	2,043,307,501
65-69	93,221	93,147	14,656	4,783	1,366,264,399	445,548,636	1,811,813,035
70-74	74,576	75,235	9,500	3,416	708,476,550	257,003,332	965,479,881
75+	119,322	116,434	8,286	4,237	988,656,204	493,299,763	1,481,955,967
TOTALS	1,866,276	1,791,876			30,998,576,118	15,858,382,986	48,338,915,071

LOCATION OF SHEET 4 IN SHORTVMT -- 018..X45

Table A.5 Sheet 5 in SHORTVMT

SHEET 5

SHORT-TERM VEHICLE MILES TRAVELED FORECASTING MODEL

FUNCTIONAL CLASS STATEWIDE VMT ESTIMATES FOR THE YEAR---------------------- 1991

	FUNTIONAL CLASS	FHWA CODE	PERCENT OF STATEWIDE VMT (%)	GROUP VMT DISTRIBUTION FACTORS (%)	STATE NETWORK RECLASSIFICATION CORRECTION FACTORS	MODEL VMT STATEWIDE ESTIMATE (annual miles)
GROUP-X	A. INTERSTATES -RURAL	01	90.94	15.3	1.016	6,841,789,946
	B. INTERSTATES -URBAN	11		12.1	0.938	4,988,316,865
	C. FREEWAYS & EXPRESSWAYS (PA) -URBAN	12		2.0	1.000	862,948,939
	D. OTHER PRINCIPAL ARTERIALS -RURAL	02		10.1	0.857	3,819,701,710
	E. OTHER PRINCIPAL ARTERIALS -URBAN	14		16.9	0.958	7,110,293,493
	F. MINOR ARTERIAL -RURAL	06		11.5	1.094	5,539,832,708
	G. MINOR ARTERIAL -URBAN	16		12.3	0.977	5,277,664,074
	H. MAJOR COLLECTOR -RURAL	07		19.8	0.975	8,482,029,068
	TOTAL (A+B+C+D+E+F+G+H)			100.0		42,922,576,803
GROUP-Y	I. MINOR COLLECTOR -RURAL	08	9.06	100.0		5,416,338,268
	J. COLLECTOR -URBAN	17				
	K. LOCAL -RURAL	09				
	L. LOCAL -URBAN	19				
	TOTAL (I+J+K+L)					5,416,338,268
	M. STATE TOTAL		100	100		48,338,915,071

NOTE : ALL VMT ESTIMATES IN THIS TABLE ARE STATWIDE ESTIMATES (annual miles)

LOCATION OF SHEET 5 IN SHORTVMT -- Z19..AH4

Table A.6 Sheet 2 in SHORTVMT

SHEET 2

SHORT-TERM VEHICLE MILES TRAVELED FORECASTING MODEL

INSTANT MACRO COMMANDS FOR PRINTING RESULTS
PRINT SHEET 1(A) INPUT DATA POP. & LIC DRVRS-----------ALT
PRINT SHEET 1(B) INPUT DATA FUNC. CLASS MILEAGES------ALT
PRINT SHEET 3 FORCAST OF LICENSED DRIVERS ------------ALT
PRINT SHEET 4 STATEWIDE VMT ESTIMATES ----------------ALT
PRINT SHEET 5 FUNCT. CLASS STATEWIDE VMT ESTIMATES ---ALT
PRINT SHEET 2 INSTANT MACRO COMMANDS FOR PRINTING ---ALT M
PRESS HOME KEY TO GET TO TOP OF PAGE
LOCATION OF SHEET 2 IN SHORTVMT -- A16..D29

Appendix B

Table B.1 Sheet 1(A) in TRACKVMT

SHEET 1(A)

VEHICLE MILES TRAVELED TRACKING MODEL

MODEL INPUT DATA		
DATA SOURCE:	FHWA HIGHWAY STATISTICS	
TRACKING YEAR:		1990
INDIANA LICENSED DRIVERS **		
AGE GROUP	MALE DRIVERS	FEMALE DRIVERS
16-19	103,639	92,948
20-24	179,807	165,042
25-29	227,451	213,490
30-34	232,295	218,259
35-39	206,830	194,307
40-44	177,977	170,912
45-49	134,699	128,636
50-54	109,767	105,039
55-59	97,208	93,387
60-64	99,020	95,138
65-69	93,382	91,394
70-74	73,286	73,623
75+	114,646	109,172
LOCATION OF SHEET 1(A) IN TRACKVMT---A1..E2		

Table B.2 Sheet 1(B) in TRACKVMT

SHEET 1 (B)

VEHICLE MILES TRAVELED TRACKING MODEL

GROUP X- FUNCTIONAL CLASS MILEAGES		MODEL AVERAGE MILEAGES
RURAL INTERSTATES	863	849
URBAN INTERSTATES	285	292
URBAN FREEWAYS AND EXPRESSWAYS	112	114
RURAL OTHER PRINCIPAL ARTERIAL	1,102	1,287
URBAN OTHER PRINCIPAL ARTERIAL	1,346	1,410
RURAL MINOR ARTERIAL	3,134	2,864
URBAN MINOR ARTERIAL	2,288	2,329
RURAL MAJOR COLLECTOR	9,754	10,021
TOTAL GROUP X MILEAGE	18,884	19,166
TOTAL STATE NETWORK MILEAGE	91,908	91,985
LOCATION OF SHEET(B) IN TRACKVMT-----F1..K15		

Table B.3 Sheet 3 in TRACKVMT

SHEET 3

VEHICLE MILES TRAVELED TRACKING MODEL

STATEWIDE VMT ESTIMATE FOR THE YEAR------- 1990

AGE GROUP	DISTRIBUTION OF LICENSED DRIVERS FOR 1990		AVERAGE ANNUAL MILES DRIVEN PER LICENSED DRIVER		STATEWIDE FORECASTS OF VEHICLE MILES TRAVELED		
	MALE (A)	FEMALE (B)	MALE (C)	FEMALE (D)	MALE (E)	FEMALE (F)	TOTAL (G)
16-19	103,639	92,948	12,733	10,643	1,319,635,387	989,245,564	2,308,880,951
20-24	179,807	165,042	18,236	11,883	3,278,960,452	1,961,194,086	5,240,154,538
25-29	227,451	213,490	20,082	12,548	4,567,670,982	2,678,872,520	7,246,543,502
30-34	232,295	218,259	20,754	8,260	4,821,050,430	1,802,819,340	6,623,869,770
35-39	206,830	194,307	16,236	12,539	3,358,091,880	2,436,415,473	5,794,507,353
40-44	177,977	170,912	19,712	9,938	3,508,282,624	1,698,523,456	5,206,806,080
45-49	134,699	128,636	18,916	6,534	2,547,966,284	840,507,624	3,388,473,908
50-54	109,767	105,039	18,685	7,056	2,051,017,251	741,155,184	2,792,172,435
55-59	97,208	93,387	17,729	6,878	1,723,448,264	642,315,786	2,365,764,050
60-64	99,020	95,138	15,522	4,796	1,537,032,009	456,281,848	1,993,313,857
65-69	93,382	91,394	14,656	5,010	1,368,629,938	457,883,940	1,826,513,877
70-74	73,286	73,623	9,500	3,987	696,217,000	293,534,901	989,751,901
75+	114,646	109,172	8,286	4,299	949,909,751	469,330,428	1,419,240,179
TOTALS	1,850,007	1,751,347			31,727,912,251	15,468,080,150	47,195,992,401

LOCATION OF SHEET 3 IN TRACKVMT --------P31..X60

Table B.4 Sheet 4 in TRACKVMT

SHEET 4

VEHICLE MILES TRAVELED TRACKING MODEL

FUNCTIONAL CLASS STATEWIDE VMT ESTIMATES FOR THE YEAR--------------------- 1990

	FUNTIONAL CLASS	FHWA CODE	PERCENT OF STATEWIDE VMT (%)	GROUP VMT DISTRIBUTION FACTORS (%)	STATE NETWORK RECLASSIFICATION CORRECTION FACTORS	MODEL VMT STATEWIDE ESTIMATE (annual miles)
GROUP-X	A. INTERSTATES -RURAL	01	90.94	15.3	1.032	6,783,020,703
	B. INTERSTATES -URBAN	11		12.1	0.991	5,144,009,191
	C. FREEWAYS & EXPRESSWAYS (PA) -URBAN	12		2.0	0.997	840,527,015
	D. OTHER PRINCIPAL ARTERIALS -RURAL	02		10.1	0.869	3,783,458,174
	E. OTHER PRINCIPAL ARTERIALS -URBAN	14		16.9	0.969	7,017,934,361
	F. MINOR ARTERIAL -RURAL	06		11.5	1.111	5,490,495,035
	G. MINOR ARTERIAL -URBAN	16		12.3	0.997	5,257,607,233
	H. MAJOR COLLECTOR -RURAL	07		19.8	0.988	8,392,822,050
	TOTAL (A+B+C+D+E+F+G+H)			100.0		42,709,873,762
GROUP-Y	I. MINOR COLLECTOR -RURAL	08	9.06	100.0		4,486,118,639
	J. COLLECTOR -URBAN	17				
	K. LOCAL -RURAL	09				
	L. LOCAL -URBAN	19				
	TOTAL (I+J+K+L)					4,486,118,639
	M. STATE TOTAL		100	100		47,195,992,401

NOTE : ALL VMT ESTIMATES IN THIS TABLE ARE STATWIDE ESTIMATES (annual miles)

LOCATION OF SHEET 4 IN TRACKVMT----AA33..AH62

Table B.5 Sheet 2 in TRACKVMT

SHEET 2

VEHICLE MILES TRAVELED TRACKING MODEL

INSTANT MACRO COMMANDS FOR PRINTING RESULTS
PRINT SHEET 1(A) INPUT DATA FOR LICENSED DRIVERS------ALT A
PRINT SHEET 1(B) INPUT DATA FUNC. CLASS MILEAGES------ALT B
PRINT SHEET 3 STATEWIDE VMT ESTIMATES ----------------ALT C
PRINT SHEET 4 FUNCT. CLASS STATEWIDE VMT ESTIMATES ---ALT D
PRINT SHEET 2 INSTANT MARCRO COMMANDS FOR PRINTING ---ALT M
PRESS HOME KEY TO GET TO TOP OF PAGE--INPUT DATA AREA
LOCATION OF SHEET 2 IN TRACKVMT----A29..E4

COVER DESIGN BY ALDO GIORGINI